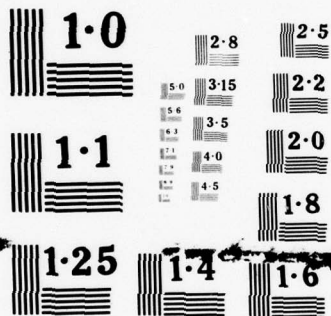


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Biological Effects of Nonionizing Electromagnetic Radiation

VOLUME III

NUMBER 3


MARCH, 1979



A DIGEST OF CURRENT LITERATURE

A Quarterly Publication Produced for
National Telecommunications and Information Administration
and United States Navy

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 **FRANKLIN RESEARCH CENTER**
Science Information Services Organization

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**BIOLOGICAL EFFECTS
OF NONIONIZING ELECTROMAGNETIC RADIATION**

A Digest of Current Literature

**A Quarterly Publication Produced for
National Telecommunications and Information Administration
and United States Navy**



*Literature Selected and Abstracted
by
Biomedical Group, Science Information Services Organization*

Bruce H. Kleinstein, Ph.D., J.D., Project Manager

Gary Freedman, Managing Editor

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BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

March, 1979 Volume III, Number 3

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PREFACE

Biological Effects of Nonionizing Electromagnetic Radiation is a publication researched and prepared by the Franklin Research Center, Science Information Services Organization, under contract with the U.S. Navy and administered by the National Telecommunications and Information Administration.

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radiofrequency radiation) are compiled, condensed, and disseminated on a regular basis. *Biological Effects of Nonionizing Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

Biological Effects of Nonionizing Electromagnetic Radiation is published quarterly. The issues of Volume III, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as summary abstracts.

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ABBREVIATIONS AND ACRONYMS

A, amp - ampere(s)
Å - angstrom(s)
BRH - Bureau of Radiological Health
C - centigrade
cm - centimeter(s)
cps - cycles per second
dB - decibel(s)
EPA - Environmental Protection Agency
FDA - Food and Drug Administration
g - gram(s)
G - Gauss
GHz - gigahertz
HEW - Health, Education, and Welfare
hr - hour
Hz - hertz
IEEE - Institute of Electronic and
Electrical Engineers
IMPI - International Microwave Power
Institute
IU - international unit(s)
J - joule(s)
k - kilo--
l - liter(s)
m - meter(s)
m - milli--
M - mega--
mho - unit of measurement of
conductivity
min - minute(s)
mo - month(s)
n - nano--

NBS - National Bureau of Standard
NIH - National Institutes of Health
NSF - National Science Foundation
NIOSH - National Institute for
Occupational Safety and
Health
NTIA - National Telecommunications
and Information Administration
NTIS - National Technical Information
Service
Oe - oersted(s)
OSHA - Occupational Safety and Health
Administration
OTP - Office of Telecommunications
Policy
PHS - Public Health Service
rad - radiation absorbed dose
R - roentgen(s)
rpm - revolutions per minute
sec - second(s)
USAFSAM - U.S. Air Force School of
Aerospace Medicine
USDA - U.S. Department of Agriculture
UV - ultraviolet
V - volt(s)
VA -Veterans Administration
W -watt(s)
Wb - Weber(s)
WHO - World Health Organization
wk - week(s)
wt - weight
yr - year(s)

μ - micro--

NEWS ITEMS

NONINVASIVE RADIO FREQUENCY PROBE DEVELOPED FOR ACCURATE TISSUE MEASUREMENTS

A researcher at the Georgia Institute of Technology, working under a 2-yr National Cancer Institute (NCI) grant, has developed a noninvasive radio frequency probe that can determine the dielectric properties of cancerous and normal tissues. Development of the probe makes possible for the first time energy absorption measurements in intact, living tumors; standard techniques involve cutting up tissue and putting it in a waveguide. Georgia Tech researcher, Everett C. Burdette explains, "We actually use the probe like a small antenna. We can model the currents along this antenna, and by measuring the change in impedance, we can predict changes in the dielectric properties." Using the probe, Burdette intends to determine the frequencies at which tumors will absorb energy more readily than normal tissues. Because the properties of tumors vary, there is no one particular frequency range that is effective. "Our goal," emphasizes Burdette, "is to find the right frequency range for each type of tumor. We have the analytical and theoretical tools here to predict exactly what the field will look like inside the body." When the measurement stage of the program is completed, Burdette expects to receive a follow-up grant from NCI to design an applicator to treat consenting cancer patients. Once Burdette confirms the frequencies where there is maximum tumor absorption and minimum normal tissue absorption, he will design special applicators for each category of diseased tissue. Based on his research with animals, Burdette feels that this technique presents a great potential for treating cancer patients. It can either be used to supplement other forms of cancer treatment, such as, chemotherapy and ionizing radiation, or eventually be used as a primary treatment.

Microwaves 17(9): 11-13; 1978.

MICROWAVE SURVEILLANCE SYSTEMS SET OFF HEALTH DISPUTE

As shoplifting losses continue to increase in shopping centers across the country, growing numbers of retailers have turned for help to surveillance systems that employ low-level microwave radiation. The system involves putting a tag on an article that, if not removed by a sales clerk or cashier, activates an alarm bell or beeper through microwaves emitted by electronic devices positioned on the sides of an entrance. Sensorimatics Electronics Corporation of Deerfield, Florida, which has manufactured more than 70% of the microwave electronic-article surveillance systems now in use, has installed more than 9,000 systems in department stores throughout the country. Store owners and manufacturers of the security device insist the low-level microwave systems are safe and point to a Stanford Research Institute study that found that under

normal operating conditions the power levels emitted by the devices are up to 10,000 times less than the microwave-exposure guidelines set by the Federal Government. Nevertheless, some clerks and cashiers are asking whether the radiation that is emitted is hazardous to their health and that of the public. In New York State, concern over the possible health hazards associated with the devices has prompted the Suffolk County Legislature to begin a series of hearings on the subject. One Suffolk County legislator, commenting on the shoplifting device, said, "We are not in any way entertaining a ban. But after we gather all the information, we could come to a conclusion that there is a threat and have to act on it."

New York Times December 18, 1978.

BRH RESEARCHER ROBERTS RUGH DIES

Dr. Roberts Rugh, a Bureau of Radiological Health (BRH) researcher in experimental embryology, died November 10 at the age of 75. Dr. Rugh came to the Bureau in 1971 after retiring as professor of radiology at Columbia University's College of Physicians and Surgeons. At the Bureau, Dr. Rugh investigated the effects of microwaves and ultrasound on the embryo and fetus, and he published 17 papers on ionizing radiation, microwaves, and ultrasound. In addition to his work at the BRH, Dr. Rugh authored five standard teaching and reference works on vertebrate development and more than 220 research papers on experimental biology.

BRH Bulletin

RADIO FREQUENCY TUMOR-TREATMENT APPARATUS PATENTED

A radio frequency apparatus that allows treatment of human tumors while inducing hypotension in the patient has been granted a U.S. patent. The apparatus enables the positioning of a patient so that the portion of the body in which the tumor is located can be heated with a radio frequency electromagnetic field for a period of time and intensity to cause necrosis of the tumor, while leaving the adjacent normal tissue unharmed. The apparatus is an improvement over existing radio frequency equipment in that it induces hypotension in the patient while treating the tumor. The apparatus bears U.S. patent number 4,119,102.

Official Gazette of the U.S. Patent and Trademark Office 975(2): 530-531; 1978.

NEWS ITEMS

IEEE PLANS SPECIAL ISSUE ON BIOMEDICAL EFFECTS AND APPLICATIONS OF ELECTROMAGNETIC ENERGY

The *Proceedings of the IEEE* will publish a special issue (January 1980) on the "Biological and Ecological Effects and Medical Applications of Electromagnetic Energy." The issue will include articles on electromagnetic fields in the environment, current safety standards, dosimetry, the biologic, behavioral, and ecologic effects of electromagnetic energy, and medical applications, such as, hyperthermia and microwave radiometry.

Bioelectromagnetics Society Newsletter

VISITING PROFESSOR TO RESEARCH ELECTROMAGNETIC FIELD THEORY TECHNIQUES AT THE UNIVERSITY OF UTAH

Dr. Ikuo Tanaka, Associate Professor of Electronics, College of Engineering, Shizuoka University, Japan, will serve for 1 yr as a Visiting Scholar at the Bioengineering Department, University of Utah, to undertake research in the area of electromagnetic field theory techniques for the internal electric fields and power absorption in man and animal models and other related research. He will be working closely with Drs. Om P. Gandhi and Carl H. Durney.

Utah Bioengineering Newsletter 6(1): 7; 1978.

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ITEMS FROM THE COMMERCE BUSINESS DAILY

☐ DETERMINATION OF THE FEASIBILITY OF AN EPIDEMIOLOGIC STUDY OF WORKERS TO RADAR.

The Environmental Protection Agency, Contracts Management Division (MD-33), Office of Administration, Research Triangle Park, NC 27711 will negotiate with the National Research Council, Medical Follow-Up Agency, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC for the above study. (July 27, 1978)

☐ BASIC RESEARCH AND DEVELOPMENT WORK IN CONNECTION WITH THE ASSESSMENTS OF THE EFFECTS OF EXPOSURE TO MICROWAVE ENERGY ON HEALTH AND THE ENVIRONMENT.

The Satellite Power System Environmental Assessment Program, Energy and Environmental Systems Division, Argonne National Laboratory, Argonne, IL is soliciting proposals for the above study. (August 9, 1978)

☐ EVALUATION OF THE POTENTIAL NEUROLOGICAL HAZARDS OF MICROWAVE FIELDS.

The Office of Naval Research, Arlington, VA has contracted with the University of Utah, Office of Research Administration, Salt Lake City, UT for the above study. (October 19, 1978)

MEETINGS AND CONFERENCES

AMERICAN THERMOGRAPHIC SOCIETY/CANADIAN THERMOGRAPHIC ASSOCIATION JOINT MEETING

Date: March 31-April 1, 1979
Place: Toronto, Canada: Sheraton Center
Sponsor: American Thermographic Society;
Canadian Thermographic Society
Requests for Information: W. B. Hobbs, M.D.,
7803 Mineral Point Road, Madison, WI 53717
Content: Clinical research in medical thermography; biological applications; veterinary and industrial applications

Place: Rotterdam, The Netherlands
Sponsor: Netherlands National Electrotechnical Committee of the IEC; Inst. of Technology Zurich
Requests for Information: Dr. T. Dvorak, ETH Zentrum-HF, 8092 Zurich, Switzerland (01) 326 2111, Ext. 2790
Content: Will include sessions on Magnetic Fields, Biological Effects, Spectrum Management, Electromagnetic Fields, Immunity and Susceptibility

BRITISH OCCUPATIONAL HYGIENE SOCIETY ANNUAL CONFERENCE

Date: April 3-6, 1979
Place: London, United Kingdom
Sponsor: British Occupational Hygiene Society
Requests for Information: D. Doran, British Occupational Hygiene Society, British Airways Medical Service, Heathrow Airport, Hounslow, Middlesex TW 6 2JA, United Kingdom
Content: Sessions will include physical, chemical, toxicological, and legislative aspects of occupational hygiene

SIXTH INTERNATIONAL CONGRESS OF RADIATION RESEARCH

Date: May 13-19, 1979
Place: Tokyo, Japan: Zenkyoren & Nihon Toshi Centers
Sponsor: International Assoc. Radiation Research (IARR); Science Council Japan (JSC); Japanese Association Radiation Research
Requests for Information: Professor S. Okada, Hongo Box 152, Bunkyo-ku, Tokyo 113-91, Japan
Content: Physics, chemistry, biology, and medicine and their interdisciplinary areas of radiation research (including nonionizing radiations) will be covered

AMERICAN OCCUPATIONAL HEALTH CONFERENCE

Date: April 29-May 4, 1979
Place: Anaheim, CA: Disneyland Hotel
Sponsor: American Occupational Medical Association (AOMA); American Assoc. of Occupational Health Nurses (AAOHN)
Requests for Information: H. N. Schultz, AOMA, 150 N. Wacker Dr., Chicago, IL 60606

MICROWAVE POWER SYMPOSIUM 1979

Date: June 11-15, 1979
Place: Monte Carlo, Monaco
Sponsor: International Microwave Power Institute
Requests for Information: Intn'l Microwave Power Institute, Box 634, SUB 11, Univ. Alberta, Edmonton, Alberta, Canada T6G 2E0
Content: Topics will include fundamental properties, microwave power generation, transmission and rectification, industrial microwave systems, microwave instrumentation and measurement, microwave properties of materials, industrial applications, food industry applications, medical and biological applications, biological effects of microwaves, domestic and catering microwave ovens, microwave field distribution and measurement, energy balance of microwave processes, equipment safety, RF interference and frequency allocations, economics and marketing of microwave ovens

INTERNATIONAL MICROWAVE SYMPOSIUM

Date: April 30-May 2, 1979
Place: Orlando, FL: Sheraton Twin Towers
Sponsor: Institute of Electrical & Electronics Engineers (IEEE), Microwave Theory & Techniques Society
Requests for Information: R. E. Henning, College of Engineering, Univ. South Florida, Tampa, FL 33620

BIOELECTROMAGNETICS SYMPOSIUM

Date: June 18-22, 1979
Place: Seattle, WA: Univ. Washington
Sponsor: USNC/URSI (Commissions A and B); Bioelectromagnetics Society
Requests for Information: A. W. Guy, Technical Program Committee Chairman, Bioelectromagnetics

INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

Date: May 1-3, 1979

MEETINGS AND CONFERENCES

Symposium, c/o Dept. Rehabilitation Medicine,
Univ. Washington School of Medicine, Seattle,
WA

XII INTERNATIONAL CONFERENCE ON MEDICAL AND BIOLOGICAL ENGINEERING/V INTERNATIONAL CONFERENCE ON MEDICAL PHYSICS

Date: August 19-24, 1979

Place: Jerusalem, Israel

Sponsor: Israel Society for Medical & Biological
Engineering (ISMBE); International Federation
for Medical & Biological Engineering (IFMBE);
International Organization for Medical Physics
(IOMP); Israel Society for Medical Physics
(ISMP)

Requests for Information: Dr. A. Werner,
Chaim Sheba Medical Center, Dept. Oncology,
Sackler School of Medicine, Tel-Hashomer,
Israel

Content: Tentative topics will include
artificial organs, biomaterials, biomechanics,
clinical engineering, diagnostic radiology,
hazards and safety, health physics, non-ion-
izing radiation, medical instrumentation,
and radiation dosimetry

WESTERN OCCUPATIONAL HEALTH CONFERENCE

Date: October 11-13, 1979

Place: San Francisco, CA: Fairmont Hotel

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Sponsor: Western Occupational Medical Assoc.
(WOMA); American Industrial Hygiene Assoc.
(AIHA); Health Physics Society (HPS);
American Society Safety Engineers (ASSE);
Western Assoc. Occupational Health Nurses
(WAOHN)

Requests for Information: B. H. Bravinder,
WOMA, Box 201, Alamo, CA 94507

RADIOLOGICAL SOCIETY OF NORTH AMERICA: ANNUAL MEETING

Date: November 25-30, 1979

Place: Atlanta, GA

Sponsor: Radiological Society of North
America (RSNA)

Requests for Information: Ms. A. Swenson,
RSNA, Suite 1150, Oak Brook Regency Towers,
1415 W. 22nd St., Oak Brook, IL 60521

FIFTH INTERNATIONAL CONGRESS OF THE INTERNATIONAL RADIATION PROTECTION ASSOCIATION

Date: March 9-14, 1980

Place: Jerusalem, Israel: Jerusalem Convention Center

Sponsor: Israel Health Physics Society; Intern'l
Radiation Protection Assoc. (IRPA)

Requests for Information: Israel Health Physics
Society, C/O Soreq Nuclear Research Center,
Yavne 70600, Israel

Content: Sessions will cover all aspects of
protection against ionizing and nonionizing
radiation

CURRENT RESEARCH

0396 EFFECTS OF WEAPONS RADIATION ON AIR-CREW TASK PERFORMANCE. Brown, G. C. (U.S. Air Force, Sch. Aerospace Medicine, San Antonio, TX 78235).

The development of mathematic models of crew survivability/vulnerability (S/V) analysis is dependent upon accurate descriptions of performance effectiveness under radiation environmental conditions. Studies of high dose, high dose-rate exposures have largely been completed. Emphasis will be placed on lower dose and dose rates, specific long mission scenarios, and complex interactions of ionizing and nonionizing radiation with task requirements. The objective of this effort is constructed dose-response curves for radiation environments and interactions of interest to SAC. Specifically, the combined effects of multiple radiation pulses, sustained low dose rate exposure, and aircrew task complexity upon system performance effectiveness will be determined. The description of aircrew performance during and following irradiation for S/V model applications (7757-05-23) is the ultimate goal. Selected models of operational task requirements will be utilized. Highly accurate simulations of specific system dynamics will be constructed and analyzed through application of mathematic control theory. Closed loop studies of operator control capabilities in radiation environments will be assessed through the identification, description, construction, and utilization of continuous (tracking) tasks. The problems of motivation, fatigue, work load, and time stress will be investigated to further strengthen S/V model predictions. (funding period n/a)

Supporting Agency: U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

0397 RFR EFFECTS ON GI TRACT. Erwin, D. N. (U.S. Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

Research is directed toward the establishment of thresholds for radio frequency radiation effects on each of the following biologic end-points: (a) smooth muscle response to direct electrical stimulation and to acetylcholine chemical stimulation; (b) smooth muscle inhibition (relaxation) and then rebound excitation (contraction) due to massive current stimulation of the gastrointestinal neural plexuses; and (c) neurophysiologic parameters of patterned firing in neurons of Auerbach's plexus. Short segments of cat gut will be exposed to a range of intensities of 2 GHz continuous wave radio frequency radiation. The following three stages of activity correspond to the above objectives. In Stage I, spontaneous and stimulated contractile activity will be monitored with strain-gauge transducers. In Stage II, coaxial electrodes in the lumen of gut segments will be used to pass massive current stimulation into the neural plexuses. Resultant relaxation and rebound contraction will be measured as above and integrated. In Stage III, fine platinum wire electrodes will be used to record ongoing activity

in the cat gut. Frequency of neural spike trains, burst pattern, and amplitude will be measured and plotted under computer control. Each of these functions will be statistically analyzed by computer and plotted as functions of intensity, time, and percent of control values. (funding period 1/78-12/78)

Supporting Agency: U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

0398 RADIOFREQUENCY RADIATION BIOEFFECTS MATH MODELS. Bell, E. L.; Cohoon, D. K. (U.S. Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

Mathematic/computer research adjunctive to laboratory experimentation will be performed to determine the effects of radio frequency radiation on living tissue. The objectives of this research are: (1) to define how radar energy is distributed in the human body and to calculate resultant temperature rises, (2) to quantify acoustic wave generation by pulsed radar and estimate tissue compression responses, and (3) to develop equations describing radio frequency effects on biochemical events including chemical reactions, metabolite diffusion in tissue, and living cell membrane effects. The results will enable prediction of the effects of radio frequency radar on human beings and will improve the quality of Air Force radio frequency radiation safety standards. The use of mathematic/computer formulations will provide estimates of effects presently unavailable through experimentation or direct measurement, improve utilization of available data, and indicate needed critical laboratory tests. To accomplish objectives 1 and 2, the relevant partial differential equations will be solved for specific model living tissues. (funding period 2/78-6/80)

Supporting Agency: U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

0399 EFFECTS OF 60 HZ FIELDS ON THE MAMMALIAN CENTRAL NERVOUS SYSTEM. Adey, W. R. (Univ. California, Sch. Medicine, Dept. Anatomy, 405 Hilgard Ave., Los Angeles, CA 90024).

The effects of 60-Hz fields from high voltage transmission lines on the central nervous system of mammals will be investigated. Environmental field conditions similar to those found in the vicinity of high voltage transmission lines will be simulated. These field gradients will range from 1 to 2,000 V/m. The effects of these fields on the biologic rhythms in rats will be evaluated. The effects on the neuroendocrine mechanism in rats will be examined by using 17-hydroxysteroids, calcium, phosphorus, vanilmandelic acid, and other urinary indicators of biorhythmicity. Changes in the neurochemistry of cat brain tissue will be studied including the measurement of both Ca^{2+} ion amino acid effluxes from the cerebral cortex. Exposure of rats to electric fields of 50 and 500 V/m have been completed. Activity measurements at 50 V/m showed

CURRENT RESEARCH

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no differences as compared with controls. At 500 V/m an increase in activity of the exposed over the controls was measured. At both 50 and 500 V/m an increase in urine output was measured with no increase in water intake. At 500 V/m no change in growth rate was observed; however, at 500 V/m a slower weight gain was measured. Thyroid and adrenal tissue were weighed at the end of exposure. Average weights of wet adrenal tissue were higher (56.8 mg) in the 500 V/m series than in the control group (43.1 mg). However, no differences were detected in averaged wet thyroid tissue weights (19.0 versus 18.5 mg). (funding period n/a)

Supporting Agency: EPA, Office of Energy Minerals & Industry

0400 INFRARED ANALYSIS OF DOSE DISTRIBUTION IN ANIMALS AND PHANTOM MODELS EXPOSED TO MICROWAVE RADIATION. Kinn, J. B.; Weil, C. M. (U.S. Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

The distribution of absorbed energy in a complex biologic system (sectioned animals) and in equivalent phantoms exposed to microwave radiation will be determined using infrared thermography. An infrared thermographic scanner has been purchased and a minicomputer/software system is being designed to collect scans. The basic picture processing software package is operational, and additional software has been designed and written. Preparation of the samples has been completed and data are being collected and analyzed for selected animals. (funding period 7/75-9/81)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0401 NEUROCHEMICAL ANALYSES ON BRAINS OF ANIMALS EXPOSED TO LOW LEVEL EMR. Bursian, S. J. (EPA, Health Effects Res. Lab., Durham, NC 27711).

The effects of low level electromagnetic radiation (EMR) on catecholaminergic and cholinergic components in various brain regions of the rat will be determined. Acetylcholinesterase activities will be determined to assess the effects of low level EMR on cholinergic components, and tyrosine hydroxylase activities will be determined to assess possible catecholaminergic alterations. Two final reports will be prepared: one dealing with the effects of 100 MHz on rat brain neurochemistry and the other dealing with the effects of 915 MHz on rat brain neurochemistry. Tyrosine hydroxylase and acetylcholinesterase activities are being measured in seven brain regions from rats exposed to 100 MHz. The results have not yet undergone statistical analysis. (funding period 3/78-9/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0402 RELATIVE EFFECTIVENESS OF PULSED VERSUS CW EXPOSURE TO EMR ON IMMUNE SYSTEM.

Smialowicz, R. J. (EPA, Health Effects Res. Lab., Durham, NC 27711).

The relative effectiveness of pulsed versus continuous wave exposure to electromagnetic radiation on the immune system of mice will be investigated. Antibody response to antigen and response to lymphocytes in vitro to mitogen stimulation will be determined in mice exposed at 425 MHz in the pulsed or continuous wave mode at several power densities for 1 hr on each of 5 consecutive days. The response to antigenic challenge with sheep erythrocytes in exposed mice will be assessed by the direct-plaque-forming cell assay. Circulating antibody titers will be determined and mitogen-stimulated response of lymphocytes will be assessed. Exposure of mice has just been initiated. (funding period 6/78-6/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0403 TDR MEASUREMENT OF DIELECTRIC PARAMETERS OF BIOLOGICAL MATERIALS. Kinn, J. B. (U.S. Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

The broadband dielectric behavior of biologic materials including tissue and micro-organisms and the frequency dependence of the complex permittivity will be examined to identify the portion most influenced by energy in the radio frequency and microwave region. Time domain reflectrometry (TDR) will be employed to study dielectric behavior. The incident and reflected pulse transmitted to the sample in a coaxial waveguide will be recorded using a minicomputer. The data will then be processed using a Fast Fourier Transform in a large computer yielding complex permittivity as a function of frequency. A hardware/software system has been designed for the CAI minicomputer. The software has been defined and is presently being written. (funding period 7/75-9/79)

Supporting Agency: EPA, Office of Res. & Development, Health Effects Res. Lab.

0404 BODY-DEFENSE-SPECIFIC ABSORPTION FREQUENCIES OF NONIONIZING RADIATION IN BIOLOGICAL SYSTEMS. Allis, J. W.; Weil, C. M.; Blackman, C. F.; Elder, J. A. (U.S. Environmental Protection Agency, Experimental Biology Div., Developmental Biology Branch, Durham, NC 27111).

The interaction of nonionizing radiation with biologic systems will be investigated to identify frequency ranges that preferentially interact with isolated molecular, subcellular, and cellular components and tissues. The interaction will be observed through changes in absorption dielectric constant or insertion/reflection loss as a function of radiation frequency. A microwave spectrometer will be constructed to determine interaction fre-

quencies in the microwave region. The results will define frequencies of interaction with biologic systems and will be used in the design of bioeffects studies using those systems. Two instrumental designs have been found not workable. A third, under study, has given preliminary evidence of reproducing literature data for one molecular system in solution. Refinement of the instrumentation and further experiments are in progress. (funding period 7/75-9/81)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0405 EFFECTS OF NONIONIZING RADIATION ON THE IMMUNE DEFENSE SYSTEM. Huang, A. T. (Duke Univ., Sch. Medicine, Box 3711, Durham, NC 27706).

This research will determine whether microwave radiation injures the immune defense system in laboratory animals, and it will define the minimum exposure that causes detectable effects. Groups of mice (4/group) will be exposed to 2,450 MHz continuous wave radiation for 30 min/day for 2, 5, 7, 9, or 10 days at power densities of 5, 15, or 30 mW/cm². The assay for immune response will comprise the in vitro stimulation of lymphocytes with T-cell mitogens (phytohemagglutinin and concanavalin A) and a B-cell mitogen (LPS) as measured by ³H-thymidine uptake. Preliminary data on the effect of microwaves on lymphocyte mitogen response, killer lymphocytes, and bone marrow colony-forming units have been recorded but not statistically analyzed. Investigation of the effect of microwaves on the morphology and chromosomes of lymphocytes has been completed. (funding period 4/75-10/78)

Supporting Agency: EPA, Office of Res. & Development, Health Effects Res. Lab.

0406 EFFECTS OF AMPLITUDE MODULATED NONIONIZING RADIATION ON MEMBRANES AND BIOPOLYMERS USING SPECTROPHOTOMETRIC AND FLUOROMETRIC MEASUREMENTS. Allis, J. W. (U.S. Environmental Protection Agency, Experimental Biology Div., Durham, NC 27111).

Amplitude-modulated or pulsed nonionizing electromagnetic radiation has been shown to affect animal behavior and the chemistry and physiology of certain isolated organ systems. These effects have been attributed to interaction between the radiation and cellular membranes, but have not been experimentally verified. This work will utilize membranes and membrane-bound enzyme systems during irradiation by amplitude-modulated radiation to determine if such effects can be inferred from changes in fluorescence or enzyme activity. Fluorometric or spectrophotometric measurements will be conducted during exposure to nonionizing radiation using equipment developed specifically for this purpose. Mode of interaction will be investigated if changes are found. A dose series for the erythrocyte membrane bound

enzyme adenosine triphosphatase has been completed at several amplitude modulation frequencies between 16 and 150 Hz. Similar measurements have been completed at one exposure level for the mitochondrial membrane bound enzyme cytochrome oxidase. Enzyme activity was measured spectrophotometrically during irradiation, and no changes were found as compared with controls. (funding period 2/76-9/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0407 APPLICATION OF FLUORESCENCE TO DETERMINE THE EFFECTS OF NONIONIZING RADIATION ON MEMBRANES AND BIOPOLYMERS. Allis, J. W. (U.S. Environmental Protection Agency, Experimental Biology Div., Developmental Biology Branch, Durham, NC 27111).

Changes in properties of biologic membranes, membrane model systems, and/or biopolymers as measured by fluorescence techniques will be defined. A fluorometer will be modified to accept a microwave exposure system so that measurements may be made during exposure of the sample. If changes in properties are found, the mode of interaction of radiation with the biologic system will be investigated. To date, the microwave exposure facility has been successfully mated to the fluorometer; exposure system parameters have been characterized showing a useful range of 500-1,700 MHz; and data have been obtained for unirradiated erythrocyte membranes using a membrane lipid probe. (funding period 7/75-9/80)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0408 MICROWAVE DOSIMETRY IN BIOLOGICAL SYSTEMS. Weil, C. M. (U.S. Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

Temperature data obtained with an infrared thermographic camera will be verified during and following microwave irradiation of phantoms using implantable temperature probes that do not perturb the microwave field. A report will be prepared detailing the results of the measurements and providing quality control validation of the thermographic camera measurements. Progress on this task is pending the completion of a data processing software package that will plot iso-temperature contours from the thermographic pictures. (funding period 10/76-12/78)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0409 DESIGN, CONSTRUCTION AND MODIFICATION OF MICROWAVE EXPOSURE SYSTEMS FOR BIOLOGICAL EXPERIMENTATION. Weil, C. M. (U.S. Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

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A simple and economic exposure system will be developed for chronic, low level exposure of squirrel monkeys to 450 MHz ultra-high-frequency radiation that will directly measure absorbed dose in each animal. The system resembles an existing one designed for exposing rodents at 915 MHz and will employ 16-inch diameter cylindrical waveguides containing a circularly polarized wave. The final output will be an exposure system consisting of approximately four in-house fabricated waveguides, each housing a single animal, plus similar enclosures for housing of sham-irradiated (control) animals. (funding period 10/76-9/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0410 BIOLOGICAL EFFECTS OF 60 HERTZ ELECTRIC FIELDS. Marino, A. A. (State Univ. New York, Sch. Medicine, Surgery, 766 Irving Ave., Syracuse, NY 13210).

The biologic effects of 60-Hz electric fields will be studied to assess the risk of exposure to such fields in the environment. Determinations will include: (a) the effect on mice of chronic exposure to 3.5 kV/m for three generations, (b) the effect on various physiologic parameters of rats of 1-30 days exposure to 3.5 kV/m, and (c) the effect of 0.5-10.0 kV/m for 1-5 days on gross motor activity of mice. Other related studies will also be performed. (funding period n/a)

Supporting Agency: HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0411 MAGNETIC FIELDS/BIOMEDICAL EFFECTS. Tenforde, T. S. (Univ. California, Lawrence Berkeley Lab., Berkeley, CA 94720).

A systematic investigation is being carried out to determine the effects of stationary and alternating magnetic fields on living organisms and man. The major goal is to assess the biologic effects of exposure to magnetic fields such as those associated with controlled thermonuclear reactors (CTR) and magnetohydrodynamic systems (MHD), and to acquire quantitative data to establish exposure guidelines for CTR and MHD workers and the populace-at-large. Physiologic parameters will be measured in experimental animals exposed to magnetic fields including food intake, urine and fecal discharge, body weight and temperature, respiration, climbing activity, blood and urine composition, plasma growth hormone and corticosterone, visual function, and cellular mitotic activity. Using a variety of cell culture lines, magnetic field effects on cell growth rate, differentiation, cytokinesis, retinal photoreceptor electrophysiology, neural regeneration, and the electron transport system will be investigated. Magnetic effects on plant cells will be examined by measuring the growth and geotropic response of *Phycomyces*, and by measuring the protoplasmic

streaming and membrane excitability in *Nitella*. The influence of magnetic fields on human subjects will be investigated, including effects on the visual system, psychomotor activities, hematopoietic, endocrine, and nervous systems. A facility that will house two large electromagnets and contain an experimental staging area is under construction. Exposure chambers and electronic devices for magnetic field studies on experimental animals and cultured cells are being constructed. Studies involving whole-animal physiology, plant growth properties and protoplasmic streaming, and neural electrophysiology have been initiated using low field strength electromagnets and permanent magnets. (funding period n/a)

Supporting Agency: Dept. Energy, Div. Biomedical & Environmental Res.

0412 MINIATURE OMNI-DIRECTIONAL RF MONITOR PROBE. Ireland, W. C. (Westinghouse Electric Corp., P.O. Box 746, Baltimore, MD 21203).

A miniature broadband electric field probe will be developed for implantation into biologic targets. Electric fields induced by incident microwave energy may then be directly measured in target organs of living animals. The design, technology, and fabrication processing necessary to construct such a probe already exist. Research will entail selection of feasible materials to be incorporated into a suitable design. Key properties of the instrument will be omnidirectionality, minimization of auxiliary equipment, suitably small physical dimensions, appropriate electrical sensitivity, freedom from interaction due to impedance of animal tissue, and low cost. (funding period 4/77-3/78)

Supporting Agency: U.S. Dept. Defense: Army, Medical Res. & Development Command

0413 TWIN-WELL CALORIMETRY SUPPORT OF IN VIVO ANIMAL STUDIES FOR WHOLE BODY EMR ABSORPTION. Kinn, J. B. (U.S. Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

The total energy absorbed in a complex biologic system exposed to electromagnetic fields will be determined experimentally. Twin-well calorimeters will be employed using in vivo animal studies for total body electromagnetic radiation absorption. Eight calorimeters have been constructed and used in studies involving rats, hamsters, and mice. (funding period 7/75-9/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0414 THERMOGRAPHY-ENHANCED BY MICROWAVE AND ACOUSTIC ENERGY. Thompson, J. E.; Simpson, T. L.; Huhns, M. N.; Caulfield, J. B. (Univ. South Carolina, Sch. Engineering, Administration Building, Room 115, Columbia, SC 29208).

Infrared thermography will be employed in conjunction with microwave and acoustic heating to diagnose malignant tumors in rats, and the relationship between observable thermographic surface effects and tumor type and location will be investigated. Optimization of detection parameters using both photographic and computer-aided image analysis will be emphasized. In particular, excitation frequency will be employed as a variable to enhance differential tumor heating for early detection. The rationale for this work is based upon other recent experiments that show that because of inherent preferential tumor energy absorption, thermographic observability is greatly enhanced by *in situ* tumor selective heating. (funding period 5/78-4/79)

Supporting Agency:HEW, PHS, NIH, NCI

- 0415 EVALUATION OF MICROWAVE OVENS AS A POTENTIAL METHOD OF STERILIZATION. Lyon, T. C.; Brunner, D. (U.S. Army, Preventive Dentistry Div., Washington, DC 20012).

This project will evaluate the ability of microwave ovens to destroy bacterial spores on non-metallic instruments and wound dressings and determine if such destruction is a function of heat alone. A commercially available microwave oven will be tested for its ability to destroy bacterial spores as a function of time, temperature, thermocouple placement, and power output. A variety of materials will be studied for their thermal capabilities during test sterilization procedures. (funding period 6/78-6/79)

Supporting Agency:U.S. Dept. Defense: Army, Medical Res. & Development Command

- 0416 RADIO FREQUENCY/MICROWAVE TERATOGENIC EFFECTS STUDY. Conover, D. (U.S. Dept. Health, Education, and Welfare, Natl. Inst. Occupational Safety & Health, Biomedical & Behavioral Science Div., 4676 Columbia Parkway, Cincinnati, OH 45226).

Human and animal studies have indicated that exposure to radio frequency (RF) radiation during gestation may induce teratogenic effects. However, little information is available concerning exposure conditions, and teratogenic data are not complete. In view of this, a pilot study will be initiated to determine the types of effects produced following irradiation of rats during gestation. Groups of animals will be irradiated at 27.12 MHz on days 1, 3, 5, 7, 9, 11, 13, and 15, after conception. Preimplantation, resorption losses, and skeletal and gross malformations will be evaluated. Follow-up studies will determine the threshold level for these effects. Work in progress under an Interagency Agreement with the National Bureau of Standards will lead to the development of a total power absorption analyzer system. The system will be employed to noninvasively determine the distribution and magnitude

of absorbed RF power to aid in extrapolating the results of the animal studies to humans. (funding period 10/76-9/80)

Supporting Agency:HEW, PHS, Center Disease Control, NIOSH

- 0417 TERATOGENIC EFFECTS OF MICROWAVE RADIATION IN RATS. Conover, D.; Foley, E.; Lary, J. (U.S. Dept. Health, Education, & Welfare, Natl. Inst. Occupational Safety & Health, 4676 Columbia Parkway, Cincinnati, OH 45226).

Groups of pregnant Sprague-Dawley rats will be exposed to microwave radiation during days 1, 3, 5, 7, 9, 11, 13, and 15 of gestation. The animals will be sacrificed on day 20. Embryos and fetuses will be examined for teratogenic effects. The number of resorptions and the amount of preimplantation loss in each dam uterus will be determined by visual inspection, and external, spinal, and skeletal defects will be assessed. (funding period 10/77-9/78)

Supporting Agency:HEW, PHS, Center Disease Control, NIOSH

- 0418 EFFECTS OF MICROWAVE IRRADIATION ON EMBRYONIC BRAIN TISSUE. Rioch, D. M. (Inst. Behavioral Res., Inc., 2429 Linden Lane, Silver Spring, MD 20910).

The behavioral effects of an 8-mo exposure to low-dose microwave radiation will be studied in rat litters. Following exposure, serial sections of two or more fetuses from each litter will be taken to determine the effects of microwave irradiation on embryonic brain tissue. (funding period 7/77-cont.)

Supporting Agency:U.S. Dept. Defense: Army, Medical Res. & Development Command, Environmental Protection Res. Div.

- 0419 RADIOFREQUENCY RADIATION MECHANISMS. Smith, G. (Georgia Inst. Technology, Sch. Engineering, Dept. Electrical Engineering, 225 North Ave. N.W., Atlanta, GA 30332).

The mechanisms of radio frequency radiation interaction with living tissue will be studied. A series of mathematical models will be developed describing the physical interaction of electromagnetic fields with tissue structures. The work will involve four levels of complexity in living tissues: (A) molecular physics, (B) details of biomolecular chemical reactions, (C) biomembrane phenomena, and (D) total tissue metabolism. The models will define the frequency dependence of the bioeffects under study, and for a given frequency, the models will suggest whether there is an amplitude threshold and/or window for the effect. For each of the above interactions, presently available models will be critically examined

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in the light of current theory and experimental data. The critical examination of each model will include a thorough treatment of the underlying physical theories and detailed evaluations of all assumptions. For each interaction, the most promising model(s) will be extended. The extensions can synthesize elements from several models or focus on one model. Available models might be rejected in favor of a new model(s). Various calculations will be performed with particular attention paid to the physical units. (funding period 7/78-12/79)

Supporting Agency: U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

0420 ASSESS SPONTANEOUS ACTIVITY AND SOCIAL BEHAVIOR OF ANIMALS CHRONICALLY EXPOSED TO LOW LEVEL EMR. Reiter, L. (EPA, Health Effects Res. Lab., Durham, NC 27711).

The effects of chronic exposure to low-level electromagnetic radiation on central nervous system development in the rat were examined. Rats were exposed 8 hr/day to 100 MHz nonionizing radiation beginning on day 6 of gestation. Offspring were examined for exposure-induced changes in neurologic and behavioral development (e.g., reflex development and locomotor activity). No differences in treatment groups were found in either development of the righting and startle responses or in the age at eye opening. In addition, locomotor activity at 30 days of age was normal. (funding period 9/75-10/78)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0421 TERATOLOGIC EFFECTS OF 915 MHz IN RATS. Berman, E.; Carter, H. (EPA, Health Effects Res. Lab., Durham, NC 27711).

To determine the teratogenicity of 915 MHz radiation in rats, animals will be exposed daily during gestation and fetuses will be examined. Circularly polarized exposure units are being assembled and exposure will begin in 1979. (funding period 8/78-6/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0422 NONINVASIVE SENSING OF SUBCUTANEOUS TEMPERATURES. Barrett, A. H.; Myers, P. C. (Massachusetts Inst. Technology, Sch. Science, Dept. Physics, 77 Massachusetts Ave., Cambridge, MA 02139).

This work will continue evaluation of the potential of microwave radiometry for diagnosis of breast cancer and other medical problems having a thermal signature. The performance of radiometers operating at 1 and 6 GHz will be compared in their ability to detect breast cancer in the same set of patients. Clinical studies will be initiated involving attempts to detect deep venous thrombosis and abdominal infections. Labora-

tory work will involve attempts to develop antennas of improved resolution and to develop a reliable antenna scanner. (funding period 9/77-8/79)

Supporting Agency: HEW, PHS, NIH, Natl. Inst. General Medical Sciences

0423 MUTAGENICITY OF 915 MHz EMR. Berman, E.; Carter, H. (EPA, Health Effects Res. Lab., Durham, NC 27711).

To determine whether 915 MHz electromagnetic radiation is mutagenic in rats, a Dominant Lethal assay will be performed following chronic exposure of male rats. Exposure and assays will be performed in 1979. (funding period 10/77-12/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0424 IDENTIFY AND DEFINE PHYSIOLOGIC VARIABLES WHICH RESPOND TO LOW-LEVELS OF MICROWAVES. Berman, E.; Carter, H.; Smalowicz, R. (EPA, Health Effects Res. Lab., Durham, NC 27711).

The physiologic status of rats will be examined following electromagnetic radiation exposure. Body fluids and metabolic variables will be examined at conditions of exposure no higher than those that cause a 2°C increase in body temperature. Studies of dose response of body temperature are almost complete. (funding period 9/78-9/80)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0425 LIFELONG ASSESSMENT OF THE BEHAVIORAL EFFECTS OF PRENATAL EXPOSURE TO MICROWAVES. Mitchell, C. L. (U.S. Dept. HEW, Natl. Inst. Environmental Health Sciences, Dept. Behavioral & Neurologic Toxicology Lab., P.O. Box 12233, Durham, NC 27709).

As the uses and power of microwave-generating devices increase, the extent to which humans and animals are exposed to microwave energy will also increase. The health implications of exposure to this type of radiation have therefore come under intense investigation. The developing organism has been shown to be more sensitive than mature adults to chemical insult and the possible long-term effects of perinatal exposure to microwave energy deserve further investigation. One recent experiment has demonstrated a decrement in performance in a conditioned avoidance procedure in offspring of female rats receiving 915 MHz continuous wave microwave irradiation at a power density of 5 mW/cm² during pregnancy. No such effects were observed in rats irradiated after birth. Moreover, preliminary experiments at the National Institute of Environmental Health Sciences have indicated that embryonic Japanese quail exposed to 2,450 MHz continuous wave microwave irradiation at a power density of 5 mW/cm² exhibit immunologic deficiencies, which become more pronounced with age. In the proposed project, the consequences of

prenatal exposure to microwave irradiation on neuro-behavioral functioning at various points during the lifetime of the progeny will be investigated. (funding period 00/78-n/a)

Supporting Agency: EPA, Office Energy Minerals & Industry

0426 EFFECTS OF MICROWAVE EXPOSURE ON INFECTIOUS AGENTS IN LABORATORY ANIMALS. Liddle, C. G. (EPA, Health Effects Res. Lab., Developmental Biology Branch, Durham, NC 27711).

To determine if microwaves alter the course of disease in animals exposed to an infectious agent, animals are infected with Type III *Streptococcus pneumoniae* and exposed to various frequencies and power densities of microwaves while the course of the disease process is monitored. The results should help to determine whether microwave exposure is deleterious to sick or debilitated individuals. This information will be useful in setting a standard for population exposure to microwaves. The first exposure group of mice infected and then exposed to 2,450 MHz microwaves at an incident power density of 10 mW/cm² for 5 hr/day for 6 days is being completed. Preliminary results indicate that at this frequency and power density there is no difference in acute mortality between the exposed animals and the sham irradiated controls. (funding period 9/77-9/81)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0427 EFFECT OF AM RADIANT ENERGY ON SMOOTH MUSCLE CONTRACTABILITY. Whitcomb, E. R. (EPA, Health Effects Res. Lab., Durham, NC 27711).

To determine if nonionizing electromagnetic energy can alter the contractability of smooth muscle in vitro, a segment of the duodenum was excised and bathed in circulating Ringer's solution. A frequency distribution of the rate of spontaneous contractions was determined before and during exposure to amplitude modulated radiant energy. The results indicated that nonionizing electromagnetic energy did not alter the myogenic properties of smooth muscle. (funding period 3/76-6/78)

Supporting Agency: EPA, Health Effects Res. Lab.

0428 GENETIC AND CELLULAR EFFECTS OF MICROWAVE RADIATION. Dutta, S. K. (Howard Univ., Sch. Liberal Arts, Dept. Botany, 2400 6th St. N.W., Washington, DC 20001).

Whether microwave radiation can affect normal cellular processes associated with the utilization of genetic information will be investigated. A battery of cellular systems, having a variety of genetic structures and functions, will be used to distinguish between perturbations caused solely by temperature rise and those caused by other mechanisms. Results to date indicate that no changes can be shown in

normal cellular processes that could not be due to temperature changes in the medium. (funding period 6/75-6/79)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0429 MICROWAVE RELATED INSTRUMENTATION SUPPORT. Ali, J. S. (EPA, Health Effects Res. Lab., Durham, NC 27711).

This project is designed to assure the operation of critical instrumentation used for chronic long-term microwave studies. Calibration of microwave instrumentation is performed routinely to guarantee dosimetric accuracy. Special electronic instrumentation is designed as needed to facilitate microwave exposures and measurement of critical parameters. Operating manuals are prepared when necessary for microwave exposure facilities. Final outputs consist of completed electronic and microwave instrumentation, such as, the design of a dual experiment microcomputer controlled behavioral testing maze system--a twelve channel electroencephalographic amplifier. To date, a humidity control system has been installed in the 100 MHz microwave exposure system; the calibration capability in the microwave area has been extended to the 0.1 to 1.0 GHz range; and microcomputer control has been added to a behavioral testing maze system. (funding period 7/74-cont.)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0430 TERATOLOGIC EFFECTS OF 100 MHz IN THE RAT. Berman, E.; Carter, H. (EPA, Health Effects Res. Lab., Durham, NC 27711).

To determine whether 100 MHz electromagnetic radiation is teratogenic in rats, animals will be exposed daily during gestation. The pilot exposure group has been completed, and the highest dose level exposures will be conducted in early 1979. (funding period 6/77-10/80)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0431 NAVY ENVIRONMENT--EFFECTS OF PULSED MICROWAVE RADIATION FROM NAVY RADAR ON MAMMALIAN BLOOD CELLS. Cleary, S. F. (Virginia Commonwealth Univ., Sch. Medicine, Dept. Biophysics, 1200 E. Broad St., Richmond, VA 23298).

Much recent research has shown that pulse-modulated microwave fields can produce alterations in biologic systems. The mechanisms of the interactions that cause these alterations are not generally understood. As a major producer of such fields from radar and other equipment, the Navy is conducting a program to determine the extent of hazard to its personnel and the public. This study is aimed at elucidating the mechanisms at the membrane level. Pulsed x-band microwave fields will be used to expose cell model

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systems consisting of human, dog, and rabbit blood cells. Studies will be made of effects on membrane permeability and cellular metabolism. The effects of the fields on membrane ion (Na^+ and K^+) fluxes will be studied to distinguish between active and passive transport alterations. In vitro studies will be carried out on the following mammalian cell lines: lymphocytes, thymocytes, polymorphonuclear leukocytes, and thrombocytes. In addition, osmotic fragility, intracellular proteins, oxygen consumption rates, and cell viability will be studied. Other studies will be carried out with the microwave field parameters as independent variables. (funding period 3/78-cont.)

Supporting Agency: U.S. Dept. Defense: Navy, Office Naval Res.

0432 ELECTROMAGNETIC INSTRUMENTATION TO ACCELERATE BONE HEALING. Bassett, C. A. (Columbia Univ., Sch. Medicine, Dept. Orthopedic Surgery, 630 W. 168th St., New York, NY 10032).

The recent demonstration in human patients that electromagnetic fields can assist in fracture healing is being exploited in a two-phase research program directed toward specifying the engineering factors required to design practical equipment for clinical evaluation in orthopedic and dental surgery. The first phase investigated pulse characteristics designed to stimulate bone repair with intermittent rather than continuous pulsing. Tissue culture procedures were used to survey a wide selection of possible pulse characteristics. These in vitro tests will be continued in the second phase. Promising pulse regimens will be tested in two animal models. The second phase will include biologic safety tests to establish that the prospective applications to reduce simple fracture repair time by half will not induce side effects. (funding period 10/76-3/80)

Supporting Agency: NSF, Div. Applied Res.

0433 DOSE-EFFECT RELATIONSHIP OF EXPOSURE TO EMR ON BLOOD-BRAIN BARRIER PERMEABILITY. Huang, A. T. (Duke Univ., Sch. Medicine, Dept. Internal Medicine, Box 3711, Durham, NC 27706).

The effect of microwave radiation on the blood-brain barrier (BBB) of the dog was studied using ^{131}I -albumin as a tracer molecule and cannulation of the cisterna magna and the femoral vein to permit multiple sampling of cerebrospinal fluid (CSF) and plasma. Measurement of the CSF:plasma distribution ratio of ^{131}I -albumin was carried out over a 5-hr period, after exposure of the dog's head for 20 min to various power densities of continuous wave microwaves at a constant frequency of 1.0 GHz. Control animals (n=11) were subjected to the same experimental conditions, but received no exposure. No effect on the BBB was observed in two dogs each at the following power densities: 2, 4, 20, 50, and 200 mW/cm². Eleven dogs were exposed to 30 mW/cm²; in two animals the penetrance of the BBB by the ^{131}I -albumin was in-

creased four to five times over controls, and two additional animals showed two- to four-fold increased penetrance. However, the CSF:plasma distribution ratios of the other animals receiving 30 mW/cm² did not differ statistically from controls. (funding period 4/75-10/78)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0434 INTERACTION OF AMPLITUDE-MODULATED (AM) NONIONIZING ELECTROMAGNETIC RADIATION WITH BIOLOGICAL SYSTEMS. Blackman, C. F. (EPA, Health Effects Res. Lab., Developmental Biology Branch, Durham, NC 27711).

The ability of amplitude modulated nonionizing radiation to cause changes in the physiologic activity of cell and tissue systems will be investigated using bench-top exposure facilities to confirm and extend previously reported results. The results to date confirm the presence of a frequency window cited by a previous researcher and demonstrate a power window in which calcium association with brain tissue is altered. (funding period 3/76-9/81)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0435 RELATIVE EFFECTIVENESS OF SHORT-TERM VERSUS LONG-TERM EMR EXPOSURE ON IMMUNE DEFENSE. Smialowicz, R. J. (EPA, Health Effects Res. Lab., Durham, NC 27711).

The effects of short-term versus long-term electromagnetic radiation exposure on the immune system of mice will be determined. And cellular and humoral immunocompetence will be determined in mice exposed to 2,450 MHz microwaves at several power densities from 0-30 mW/cm² for 15-30 min daily for 1-22 consecutive days. Parameters to be examined include: colonic temperature; blood counts; immunocompetence employing in vitro-mitogen stimulated lymphocyte response; frequencies of T- and B-lymphocytes; and antibody response to sheep erythrocytes. No significant differences in the hematologic or immunologic indices examined have been observed between sham- and microwave-exposed mice. The duration of microwave exposure does not appear to affect the immune function. (funding period 1/78-9/78)

Supporting Agency: EPA, Office Res. & Development, Health Effects Res. Lab.

0436 NAVY ENVIRONMENT: MICROWAVE DISPERSION AND ABSORPTION IN TISSUE: MOLECULAR MECHANISMS. Foster, K. R. (Univ. Pennsylvania, Sch. Engineering & Applied Science, Dept. Bioengineering, 4001 Spruce St., Philadelphia, PA 19104).

This research is part of the Navy's ongoing program to elucidate the basis for alterations in biologic tissue resulting from microwaves and other electro-

magnetic fields. This research specifically seeks to increase the data base relating to the dielectric permittivity of tissue on a macroscopic and microscopic level. The dielectric properties of various tissues over the frequency range of 0.1 to 18 GHz will be examined. Measurements will be made by confining the sample in a coaxial line or waveguide section that is terminated in a known impedance. Using a slotted line, the standing wave pattern in front of the sample will be measured allowing calculation of the dielectric properties of the material. Special emphasis will be placed on bound and free water. Molecular mechanisms that result in microwave absorption will be studied as functions of frequency and temperature. (funding period 4/78-cont.)

Supporting Agency: U.S. Dept. Defense: Navy, Office Naval Res.

0437 EFFECTS OF MICROWAVE RADIATION ON NEURAL RESPONSE AND THE CENTRAL NERVOUS SYSTEM.
McRee, D. J. (U.S. Dept. HEW, Natl. Inst. Environmental Health Sciences, P.O. Box 12233, Durham, NC 27709).

With the possible exception of thermal effects, the basic mechanisms of interactions between microwave radiation and biologic systems is largely unknown. Research is needed to detect and define the effects of microwave radiation on specific tissues and organs. Several reports have indicated that microwaves can affect the central nervous system and it has been suggested that microwave radiation may directly affect neuronal function. In view of this, isolated nerve preparations will be exposed to different microwave frequencies, intensities, and modulations to determine whether microwave radiation has a direct effect on nerve function. One possible site of interaction may be the neuronal membrane since it plays an important role in maintaining the ionic gradients that are

necessary for the propagation of electrical impulses. Preliminary experiments have shown that microwave irradiation causes a faster rundown of nerves that are continuously stimulated. These experiments will be continued to determine whether microwaves have a direct effect on membrane permeability to cations. (funding period 00/78-n/a)

Supporting Agency: EPA, Office Energy Minerals & Industry

0438 FACTORS DETERMINING THE RADIOSENSITIVITY OF CANCER CELLS AND THEIR MODIFICATION.

Sugahara, T.; Yoshii, G.; Nikaido, O.; Aoyama, T.; Kano, E. (Kyoto Univ., Sch. Medicine, Dept. Experimental Biology, Yoshida-Konoe-cho Sakyo-ku Kyoto, Kyoto, Japan 606).

Factors determining the radiosensitivity of tumor and normal cells will be analyzed and their possible modification will be tested in cultured cells and experimental tumors. New methods applicable to human tumor therapy will be proposed from these studies. Various tissue culture techniques of mammalian cells will be applied to analyze the modification of radiosensitivity by factors, such as, hypoxic sensitizers, chemical protectors, hyperthermia, PLDR inhibitors, cell cycle, radiosensitive human genetic disorders, and cell-to-cell interaction. Some of these factors will be tested on experimental tumors in which not only the cure rate and survival time but also quantitative hematologic markers will be used as criteria. A hyperthermia apparatus employing ultrasound and high frequency electromagnetic fields will be developed and tested. (funding period 00/78-n/a)

Supporting Agency: Japanese Ministry Education Science & Culture, Tokyo

CURRENT LITERATURE

- 5911 MICROWAVE TRANSMISSION THROUGH NORMAL AND TUMOR CELLS. (Eng.) Hershberger, W. D. (Dept. Electrical Sciences and Engineering, Sch. Engineering and Applied Science, Univ. California, Los Angeles, CA 90024). *IEEE Trans Microwave Theory Tech* 26(8): 618-619; 1978. (2 refs)

Variations in results from studies on microwave transmission through normal and tumor cells are discussed, with particular reference to methods used to control the frequency selectivity of the equipment employed. In one study where a frequency range of 66-76 GHz was used, curves displaying a cyclic resonance were obtained for eight different test substances including a variety of normal and tumor cells as well as such compounds as guanine and guanylic acid. These curves had a remarkable similarity, and it is suggested that it would be a striking coincidence if these diverse materials were characterized by similar frequency characteristics. In another study where a frequency range of 76-86 GHz was used, the corresponding curves displayed some dissimilarity, but a cyclic character was apparent in most of them. In both studies, the authors were not clear on the effectiveness of the means used to control standing waves, and they did not give a numeric value for the standing wave ratio in the system. The following procedure is proposed for distinguishing between losses due to the sample and the frequency selectivity of the microwave measuring system. The system is first adjusted for a standing wave ratio of unity. After this is done, if a frequency-dependent absorption arises on introduction of the sample or substitution of one sample for another is still observed, then the observed selectivity may be attributed to the material rather than to the measuring system. It is suggested that the above ambiguities in the results reported will be resolved only when more information on the procedures used to control frequency selectivity is presented.

- 5912 EFFECT OF MICROWAVES OF MILLIMETER RANGE ON HUMANS AND ANIMALS. (Rus.) Zaliubovskaia, N. P. (I. I. Mechnikov Kharkov Scientific Res. Inst. Microbiology, Vaccines and Sera, Kharkov, USSR); Kiselev, R. I. *Gig Sanit* (8): 35-39; 1978. (3 refs)

The effect of millimeter range waves on humans and CBA mice was studied. Seventy-two workers, aged 20-50 yr, who have been exposed occupationally to the radiation emitted by super-high-frequency generators for 1-10 yr, were under medical observation for 3 yr. They complained of fatigue, sleepiness, headache, and impaired memory. Reduced hemoglobin level and erythrocyte count, reduced color index of blood, tendency to hypercoagulation, reduced leukocyte count (to 4,100 from 4,710/mm³ versus 5,980/mm³ in the controls), increased lymphocyte count (30,300-37,800/mm³ versus 22,900/mm³ in the controls), 20% reduction of the segmented neutrophils, 18% reduction of the osmotic resistance, and 26% reduction of the acid resistance of the erythrocytes were observed. Immunologic investigations revealed reduced bactericidal activity of

the skin (63-65.2 versus 79.9 in the controls), reduced lysozyme level (160 versus 320 in the controls), reduced complement titer (10 versus 20), reduced phagocytic activity (18.3-20.1 versus 25.7), and reduced phagocytic index (0.6-0.7 versus 1 in the controls). In another experiment, 250 mice were exposed to an electromagnetic field (wavelength 6.50 mm, energy density 1,000 μ W/cm², 15 min/day for 20 days). The experiment revealed reduced leukocyte count (6,100/mm³ versus 7,200/mm³ in the controls), reduced phagocytic activity (19.6% versus 32.3%), lowered phagocytic index (0.56 versus 1), reduced lysozyme level (40 versus 160), reduced complement titer (10 versus 25), and reduced bactericidal activity of the skin (57% versus 98%). Increased plasma 17-oxyketosteroid level, reduced ascorbic acid level in the tissues, increased epinephrine levels in the blood, hypothalamus, and adrenals, increased norepinephrine levels in the blood and adrenals, and reduced norepinephrine level in the hypothalamus were measured. The findings indicate that exposure to microwaves induced depression of the immunobiologic reactivity and changes in the hypophyseal-adrenal and sympathicoadrenal systems.

- 5913 NEUROVEGETATIVE BALANCE AND DIENCEPHALIC FUNCTION IN PREDISPOSED SUBJECTS AND GEOMAGNETIC ACTIVITY CHANGES. (Cze.) Zdichynec, B. (Interni oddeleni nemocnice, OUNZ Pelhrimov, 394 64 Pocatky, Czechoslovakia); Valnicek, B. *Čas Lek Cesk* 117(25): 785-787; 1978. (8 refs)

The influence of geomagnetic activity changes on the neurovegetative balance and diencephalic function was studied in predisposed subjects (14 men aged 50-58 yr with ischemic heart disease, 12 men 48-59-yr-old with chronic cor pulmonale, and 10 men with transitory cerebrovascular episodes) and in 11 clinically healthy persons of the same age. Unlike in the healthy controls, the tests showed statistically significant changes in most of the predisposed patients on critical days of geomagnetic activity (15 gamma/min or higher). The test parameters increased on such days, and so did the necessary doses of nitroglycerine, Syntophylline, and diazepam. These changes were even more pronounced during the simultaneous occurrence of high geomagnetic activity and frequent meteorotropic front changes.

- 5914 EFFECT OF SINUS-MODULATED CURRENTS ON THE ³²P RESORPTION FROM THE SYNOVIAL MEMBRANE OF THE KNEE JOINT UNDER MUSCULAR ACTIVITY. (Ukr.) Derbish, G. V. (Odessa Inst. Agriculture, Odessa, USSR); Faitel'berg-Blank, V. R. *Dopov Akad Nauk Ukr* 13(6): 547-550; 1978. (9 refs)

The effects of treatment with sinus-modulated current (40 or 150 Hz, 50% modulation) under static, dynamic, and mixed loads on the resorption of ³²P from the knee joint into the blood were studied in 45 male dogs. The ³²P resorption was determined by measuring the radioactivity in blood drawn from the auricular vein. The resorption of

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^{32}P through the synovial membrane was increased by the electric current against the background of static and mixed loading, but it was inhibited by the current under dynamic loading.

- 5915 INVESTIGATION OF THE ACTIVITY OF CERTAIN ENZYMATIC SYSTEMS UNDER THE EFFECT OF SUPER-HIGH-FREQUENCY ELECTROMAGNETIC FIELD. (Rus.) Dumanskii, Iu. D. (A. N. Marzeev Kiev Scientific Res. Inst. General and Communal Hygiene, Kiev, USSR); Tomashevskaya, L. A. *Gig Sanit* (8): 23-28; 1978. (10 refs)

The effect of microwave irradiation ($2,375 \pm 50$ MHz, energy density 10, 100, or $1,000 \mu\text{W}/\text{cm}^2$, 2 hr/day, 4 mo) on the sub-cellular activity of enzyme systems of the liver and brain was studied in 160 male albino rats. Irradiation at the lowest intensity level caused no significant changes, but exposure to 100 and $1,000 \mu\text{W}/\text{cm}^2$ caused a reduction by about 30% in the cytochrome oxidase activity in the liver mitochondria, and 20-40% reduction of the enzyme activity in the brain mitochondria. The enzyme activity returned to normal 2 mo after the irradiation. The glucose-6-phosphate dehydrogenase activity of the liver and brain increased by 25-35% during the irradiation. The irradiation at the intensities of 100 and $1,000 \mu\text{W}/\text{cm}^2$ caused significant increase in the amidopyrine demethylating activity ($p < 0.02-0.05$) and in the aniline hydroxylating activity of the liver ($p < 0.02-0.05$) during the irradiation. Normalization was seen 2 mo after exposure. The findings indicate the marked effect of microwaves on major biochemical parameters.

- 5916 INHIBITION OF TUMOR GROWTH IN MICE BY MICROWAVE HYPERTHERMIA, POLYRIBOINOSINIC-POLYRIBOCYTIDYLIC, AND MOUSE INTERFERON. (Eng.) Szmigielski, S. (Center for Radiobiology and Radioprotection, 00-909 Warsaw, Poland); Bielec, M.; Janiak, M.; Kobus, M.; Luczak, M.; De Clercq, E. *IEEE Trans Microwave Theory Tech* 26(8): 520-522; 1978. (32 refs)

The tumor inhibiting effect of microwave hyperthermia alone or in combination with polyriboinosinic acid-polyribocytidylic acid (poly I-poly C) and/or mouse interferon was examined in mice bearing sarcoma 180 tumors. Mice were irradiated with 3,000-MHz microwaves at a power density of $40 \text{ mW}/\text{cm}^2$ for 2 hr daily from day 2 to day 15 after tumor transplantation. Some mice also received daily injections of poly I-poly C ($2 \mu\text{g}/\text{g}$) and/or mouse interferon (100 international units/g). Microwave irradiation, which produced a 3-4°C increase in rectal temperature, resulted in prolonged survival. On day 28 after tumor transplantation, 8 of 24 mice were still alive, while all control mice died before day 26. When microwave hyperthermia was combined with poly I-poly C, 12 of 24 mice were alive on day 28. While no tumor regression was noted in control mice, tumors regressed in 12 of 24 mice irradiated with microwaves. The combination of microwave irradiation, poly I-poly C, and interferon resulted in tumor regression in 16 out of 24 mice. Tumors harvested

on day 16 after transplantation were significantly larger in control mice (mean, 1.36 g) than in mice exposed to microwave hyperthermia (mean, 0.96 g) or hyperthermia combined with other treatments. The combination of microwave hyperthermia, poly I-poly C, and interferon resulted in the most pronounced reduction in tumor mass (mean, 0.57 g). The rate of incorporation of radiolabeled thymidine, uridine, or glycine as well as the intracellular levels of cyclic adenosine monophosphate did not show a strict correlation with tumor mass or percentage of regressed tumors. In general, a decreased incorporation of thymidine and glycine was observed in mice exposed to microwave hyperthermia alone or in combination with poly I-poly C and/or interferon treatment.

- 5917 TECHNIQUES FOR UNIFORM AND REPLICABLE MICROWAVE HYPERTHERMIA OF A MODEL MOUSE CARCINOMA. (Eng.) Robinson, J. E. (Div. Radiation Res., Univ. Maryland Sch. Medicine, Baltimore, MD 21211); Cheung, A. Y.; Samaras, G. M.; McCulloch, D. *IEEE Trans Microwave Theory Tech* 26(8): 546-549; 1978. (11 refs)

Two techniques for localized 2,450-MHz microwave hyperthermia of experimental mouse carcinoma are described. In one approach, which involves free-field heating, 1-cm tumors are encapsulated within a 5-cm spherical mass of tissue-equivalent phantom material and are then placed in an anechoic chamber on an equipower surface. As currently developed, this free-field microwave technique may be used to administer local hyperthermia to a model 1-cm tumor system situated on the mouse flank. Encapsulation within a tissue-equivalent bolus yields excellent temperature uniformity within the tumor and a stable coupling geometry, which may be replicated for batch treatment of tumors in the far field. An applicator approach is also described in which tissues are immersed in a temperature-controlled tissue-equivalent liquid bolus (80% isotonic saline and 20% ethanol by weight) and are irradiated by time-multiplexed parallel-opposed beams. The liquid improves thermal coupling between the bolus and tumor. With the inherent ability of the liquid to be well stirred and temperature regulated outside of the microwave field, excellent heating results on flank tumors immersed in the solution have been obtained.

- 5918 INTERACTION BETWEEN 2450-MHZ MICROWAVES AND IONIZING RADIATION IN *TRIBOLIUM CONFUSUM*. (Eng.) Lai, P.-K. (Dept. Radiology, Univ. Pittsburgh Medical Sch., Pittsburgh, PA); Cain, C. A.; Ducoff, H. S. *IEEE Trans Microwave Theory Tech* 26(8): 530-534; 1978. (26 refs)

The potentiating effect of a 2-hr treatment with 2,450-MHz microwave radiation (specific absorption rates of 680 or 760 W/kg in distilled water) on single or fractionated gamma radiation was investigated in the flour beetle *Tribolium confusum*. Microwave irradiation in immediate sequence with ionizing radiation enhanced the effect of the

latter, regardless of the order of application. When microwave treatment followed gamma irradiation, the interaction of the two modalities was detectable only if they were separated by less than 60 min. When microwave irradiation was performed before gamma irradiation, the enhancing effect persisted for at least 8 hr. At the higher specific absorption rate of 760 W/kg, the sparing effect of dose fractionation was completely abolished by microwave irradiation for interfraction intervals as long as 36 hr. Split dose repair was delayed for only 8-10 hr when the lower specific absorption rate of 680 W/kg was used for microwave irradiation, and eventually survival increased. All of these microwave effects are very similar to those of water immersion hyperthermia on the response to single or fractionated gamma irradiation, and it appears that the sensitizing effect of microwaves on damage caused by ionizing radiation can be attributed entirely to heating by the microwave irradiation. The above results emphasize the likelihood that the synergistic interaction between hyperthermia and ionizing radiation results from the impairment by heat of the capacity to repair DNA damaged by the ionizing radiation. Hyperthermia could impair this repair capacity by the denaturation of enzymes necessary for repair or by the alteration of the integrity of the DNA-nuclear protein-membrane lipoprotein complex, which appears to play a role in the repair.

- 5919 THE PERFORMANCE OF A NEW DIRECT CONTACT APPLICATOR FOR MICROWAVE DIATHERMY. (Eng.) Kantor, G. (Div. Electronic Products, Bureau Radiological Health, FDA, 5600 Fishers Lane, Rockville, MD 20857); Witters, D. M.; Greiser, J. W. *IEEE Trans Microwave Theory Tech* 26(8): 563-568; 1978. (8 refs)

A direct contact applicator designed for microwave diathermy at a frequency of 2.45 GHz is described. The applicator has an aperture diameter of 15.2 cm. The far field beamwidth is 55.5 degrees, and the maximum input power carrying capability is 300 W continuous wave. The housing, with a diameter of 9.5 cm, consists mainly of a circular waveguide. At its output end, the conical flare horn section with a diameter of 12.9 cm is surrounded by an annular choke to control leakage. Two sets of dual posts, opposite to each other, are placed in the forward part of the guide at 45 degrees to the probe to generate a circularly polarized field. The significant near field components of the therapeutic beam are in a transverse plane, parallel to the aperture. The maximum power density at the center of the therapeutic beam is 15.7 mW/cm²/W of forward power, and the minimum in front of the outside diameter of the choke is 0.13 mW/cm²/W of forward power. Heating patterns on the exposed surface of muscle phantoms and inside fat-muscle phantoms are spatially similar and relatively uniform. The maximum leakage for direct contact loading is 0.8 mW/cm²/100 W of forward power and 4 mW/cm²/100 W of forward power with an air space of 1 cm between the applicator and phantom. The applicator is also a viable candidate for hyperthermia.

- 5920 CELL LOSS AFTER COMBINED THERMORADIOGRAPHY. DETERMINATION IN VIVO OF CELL LOSS RATE OF EUOIC AND HYPOIC CELLS OF EXPERIMENTAL TUMORS. (Ger.) Dietzel, F. (Abteilung Nuklearmedizin, Zentrum für Radiologie, Justus-Liebig-Universität Gießen, Friedrichstrasse 25, 63 Gießen, W. Germany); Linhart, G.; Bierbrauer, J.; Heil, T. *Strahlentherapie* 154(8): 564-570; 1978. (27 refs)

The effects of x-ray irradiation (single tumor dose 2,000 R) and hyperthermia (461.04 MHz, 150 W, duration 2 min, 40.5 C), alone and in combination (with x-ray treatment immediately after or before hyperthermia) on tumor cell death was studied in NMR1 mice with implanted solid Ehrlich carcinoma of the neck. The tumor volume was 1 ml at the time of the treatment. The cell death was measured as the reduction of DNA labeling between the 96th and 192nd hr after the intraperitoneal administration of ¹²⁵I-deoxyuridine before treatment. Both hypoxic and euoxic tumor cells were labeled. While x-ray irradiation alone tended to destroy mainly euoxic cells, intensive hyperthermia alone (4 min, 43 C) destroyed mainly hypoxic cells. Mild hyperthermia (2 min, 40.5 C) did not influence the x-ray induced cell loss significantly. When combined with x-ray treatment, mild hyperthermia increased the loss of hypoxic cells to the rate of the euoxic cells.

- 5921 STUDY OF THE EFFECT OF ELECTROMAGNETIC FIELDS ON THE ACTIVITY OF ENZYMES. (Rus.) Arber, S. L. (Moscow, USSR). *Elektron Obrab Mater* (1): 63-65; 1978. (10 refs)

General thermal analysis is used to explain the fact that electromagnetic fields either cause no change or reduce the enzyme activities in biologic systems. Enzymatic catalysis requires an exact orientation of the catalytic groups. If these groups are polar, exposure to an electromagnetic field slows down the enzymatic reaction in the biologic system exposed. The polar substrate may also be affected by the electromagnetic field.

- 5922 SELECTIVE HEATING OF CUTANEOUS HUMAN TUMORS AT 27.12 MHZ. (Eng.) Antich, P. P. (Mount Sinai Sch. Medicine, New York, NY 10029); Tokita, N.; Kim, J. H.; Hahn, E. W. *IEEE Trans Microwave Theory Tech* 26(8): 569-572; 1978. (5 refs)

Radiofrequency (27.12 MHz) heating of cutaneous tumors was performed in a preliminary study of 12 patients to determine if tissue temperature could be correlated with absorbed power and to investigate the possibility of a temperature differential between tumor and normal tissue. Distributions of the time at which the temperature reached its maximum and of the value of the maximum temperature were analyzed for both normal tissues and tumors. A normalized histogram of the time at which the maximum of temperature was reached showed that the curve was a Gaussian fit to the

normal tissue data with a mean value of 10.8 min and a standard deviation of 4.4 min. The normalized histogram of the maximum temperatures in normal and tumor tissue showed the Gaussian fit the normal tissue data and had a mean temperature of 40.6 C and a standard deviation of 1.4 C. The tumor distributions were broader and displayed tails for temperatures and times larger than those of normal tissues. A selective heating effect of tumors was observed, indicating that it is possible to induce localized hyperthermia by localized inductive heating, at least in the case of superficial tumors. A correlation was observed between absorbed power and average temperature, indicating that a dosimetry based on the measurement of absorbed power is capable of giving a degree of description of the ensuing thermal field. In this description, normal tissue temperatures would be well defined, while for tumors a range of temperatures would be obtained with a predictable minimum value.

- 5923 EFFECT OF WEAK MAGNETIC FIELDS ON GROWTH OF CELLS IN TISSUE CULTURE. (Eng.) Sutherland, R. M. (Ontario Cancer Treatment and Res. Foundation, Univ. Western Ontario, London, Ontario, Canada); Marton, J. P.; MacDonald, J. C.; Howell, R. L. *Physiol Chem Phys* 10(2): 125-131; 1978. (20 refs)

Normal Chinese hamster V79 lung cells were grown in vitro for more than 1 yr in a magnetic field of less than 10^{-7} tesla to test the hypothesized effects of weak magnetic fields on biologic systems. Within the limits of experimental errors inherent in these experiments, there was no difference in the growth rate, appearance, or colony size of cells grown in this low magnetic field versus control cells grown in a normal magnetic field. The results, however, cannot confirm or deny the hypothesis regarding the effects of low magnetic fields on biological systems, which includes a possible effect on cell growth. In its present stage of development, the hypothesis, which is based on the existence of biosuperconductivity, suggests only that normal cell growth in the absence of a magnetic field should be slower than in the normal geomagnetic field. If this difference is very small, its presence may be masked by random errors in the data.

- 5924 CORRELATION BETWEEN MAGNETIC STORMS DUE TO SOLAR SPOTS AND PIGEON HOMING PERFORMANCES. (Eng.) Schreiber, B. (Zoology Inst., Univ. Parma, 43100 Parma, Italy); Rossi, O. *IEEE Trans Magnet* 14(5): 961-963; 1978. (18 refs)

Pigeon homing performance is studied in relation to solar spot-induced magnetic storms to determine if any correlation exists. In one study, observations concerning 18 pigeon races held from 1932-1957 involving a total of 12,000 pigeons were analyzed. There was a highly meaningful negative correlation ($r = -0.7$) between sun spot numbers and the percentage of pigeons that arrived before

the first nightfall. In a second study involving races at two different locations between the years 1957 and 1976, the efficiency of homing was measured by the speed of the first arrival and the time elapsed between the first and the last arrived pigeon in the first 10%. For races at one location, a negative correlation between solar activity and homing capability was clearly demonstrated ($r = -0.77$). The results were further confirmed by the positive correlation between the Wolf numbers of solar spots and the spread of the first 10% of the arrivals. For the other location, the same correlation was not so evident, since the data were rather spread ($r = -0.225$). The reason for the differences between these two locations was not very clear. However, they may be due to differences between the two groups of races, which may have affected the performance of the birds. In general, however, it seems that the correlation between homing efficiency and solar spots is clearly demonstrated.

- 5925 CAN ELECTROMAGNETISM ACCOUNT FOR EXTRA-SENSORY PHENOMENA? (Eng.) Balanovski, E. (Dept. Mathematics, King's Coll., London WC2, England). Taylor, J. G. *Nature* 276(5683): 64-67; 1978. (10 refs)

Electromagnetic (EM) detectors covering a wide range of frequencies were used to search for unusual EM radiation emitted by subjects performing alleged extrasensory phenomena. No abnormal EM emission was detected from any of the subjects during the following activities: psychokinesis, metal bending, psychic healing, dowsing, and telepathy. In addition, tests of human sensitivity to low levels of EM radiation were performed using a tuneable radio frequency source in the frequency range of 220-950 MHz with a power output of 1 mW and a tuneable microwave source (both pulsed and continuous wave) in the frequency range of 6-17 GHz with a power level of 5 mW. No indication of human sensitivity to low levels of EM radiation was found.

- 5926 EFFECT OF PLEXIGLAS ANIMAL HOLDERS ON MICROWAVE ENERGY ABSORPTION. (Eng.) Ho, H. S. (Bureau Radiological Health, Food and Drug Admin., Rockville, MD 20852). *IEEE Trans Biomed Eng* 25(5): 474-476; 1978. (12 refs)

The patterns of microwave energy absorption in three homogeneous cylindrical muscle-equivalent models of small animals with and without cylindrical Plexiglas holders were calculated along with the perturbed exposure fields in plane wave irradiated empty holders to compare the relative magnitudes of the perturbation of these two dosimetric quantities. Calculations were made separately for polarizations where the electric field (TM) and the magnetic field (TE) of an incident 2,450-MHz plane wave were parallel to the axis of the cylinder. Three sizes of the animal cylinder corresponding to radii of 2, 3, and 5 cm were used. Two sets of holders were used for each phantom animal. One set of holders (type T) fit the phan-

toms exactly so that the inside radius of each holder was equal to the corresponding radius of the animal cylinder. Another set of holders (type A) had inside radii twice that of their corresponding animal cylinders so that air spaces existed between the animal cylinders and the walls of their holders. For each animal cylinder, the perturbations of the exposure field and the absorbed dose rate were smaller for the type T holder than for the type A holder. The TM polarized case showed more perturbation than the TE polarized case. Perturbations increased with the size and corresponding thickness of the holder to as much as 14.3 dB. However, the perturbation of the absorbed dose rate was typically less than 1 dB and was much smaller than that of the corresponding exposure field. The only exception was the -2.26 dB perturbation of the internal peak of the largest animal cylinder by the type A holder for the TM case. However, this internal peak was only 7% of the absolute peak at the surface. The above results indicate that large perturbations of the exposure field due to Plexiglas holders do not automatically result in a correspondingly large perturbation of the absorbed dose rate in the animal.

5927 CAPACITIVE STIMULATORY EFFECT IN MAGNETIC STIMULATION OF NERVE TISSUE. (Eng.)

Ueno, S. (Dept. Electronics, Kyushu Univ., Fukuoka, 812, Japan); Matsumoto, S.; Harada, K.; Oomura, Y. *IEEE Trans Magnetics* 14(5): 958-960; 1978. (4 refs)

The capacitive stimulatory effect of two different contactless stimulating methods designed to avoid the deficiencies of conventional galvanic stimulation are studied in frog nerve-muscle preparations. The first method stimulated the nerve by means of voltage pulses through windings on a permalloy core through which the nerve bundle was threaded. Measurements of the pulse strength-duration curve indicated a chronaxy of 20 μ sec, which is shorter by one decade than the 0.3 msec pulse duration for galvanic stimulation. This phenomenon can be simulated by a capacitive effect. A capacitor was inserted between the pulse generator and the nerve bundle, and the strength-duration curves were plotted for various values of capacitance. The chronaxy became 20 μ sec at capacitances equal to 150-500 picofarads. The other contactless stimulating method involved exciting the nerve by means of a high frequency magnetic field generated in the airgap of a ferrite core driven by burst signals. The voltage threshold for nerve excitation reached a minimum near a frequency of 1 kHz. In this second method of contactless stimulation, the loop currents or eddy currents were induced locally in the nerve tissue by the high frequency magnetic field; whereas, in the first method, the membrane capacitance was charged directly by the electromotive force generated by the electromagnetic induction. In both cases, however, two typical characteristics, the strength-duration curve and the threshold-versus-frequency curve, were explained well by a capacitive coupling model.

5928 THERMOGRAPHIC TUMOR DETECTION ENHANCEMENT USING MICROWAVE HEATING. (Eng.) Thompson, J. E. (Coll. Engineering, Univ. South Carolina, Columbia, SC 29208); Simpson, T. L.; Caulfield, J. B. *IEEE Trans Microwave Theory Tech* 26(8): 573-580; 1978. (24 refs)

Experiments with transplantable guinea pig liver hepatomas were performed to demonstrate that increased thermographic observability of the tumors can be obtained by microwave heating of the tumor area. The experiments showed that the temperature differential between healthy tissue and tumor tissue can be increased substantially by irradiating the examined area with microwave radiation. The increased spatial temperature gradients are then more easily observed using conventional thermographic techniques, resulting in an improvement in the sensitivity of the basic thermographic technique. When transplantable guinea pig hepatomas were irradiated for 75 sec with 2.45-GHz microwave radiation, a tumor temperature rise of 5.5 C was observed along with a rise of 2.5 C in the surrounding healthy tissue. The spatial gradient was 3 C, which compares with the relevant unheated spatial gradient of approximately 0.5 C. The thermographic raw data are produced in the form of temperature profile maps, and the spatial data obtained are used to determine the presence and location of a tumor. This is additionally facilitated by observing thermographically the temporal behavior of the tumor heating and cooling. These temporal data may prove to be useful in quantifying such tumor characteristics as depth, vascularity, or size. The microwave power and required irradiation times are small and result in a maximum healthy tissue temperature increase of only a few degrees Celsius.

5929 RADIOFREQUENCY THERMONEUROTOMY OF PERIPHERAL NERVES FOR CONTROL OF TRIGEMINAL NEURALGIA. (Eng.) Gregg, J. M. (Dental Res. Center, The Univ. North Carolina, Chapel Hill, NC 27514); Banerjee, T.; Ghia, J. N.; Campbell, R. *Pain* 5(3): 231-243; 1978. (38 refs)

Radio frequency thermoneurolysis (RFTN) was performed in the peripheral infraorbital and inferior alveolar nerves of eight patients with either post-traumatic or idiopathic paroxysmal trigeminal neuralgias to achieve pain relief. Facial pain was significantly relieved in seven of these eight patients following RFTN. In these instances pain was typically reported to gradually subside over the first 2-3 postoperative days. Three patients rated pain severity at zero for the first 9 postoperative mo, and four patients reported pain to be improved to a mild level of less than 25%, a level that remained constant for 12 mo. Repeated study of subjective postoperative pain with the Melzack pain language questionnaire indicated a loss of the explosive, triggered, and paroxysmal pain component and the retention of a duller throbbing pain. Two of the seven successfully controlled patients experienced recurrences of symptoms at postoperative mo 12. Tests of tactile-discriminative functions

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revealed small initial deficit at 1 wk after treatment, but no long-term significant measurable differences from preoperative baselines were evident. Significant post-treatment elevations of mean pain detection and pain tolerance thresholds were observed in this series. No major complications were observed. It is concluded that RFTN is an effective means of controlling the pain of trigeminal neuralgia. It is indicated when alternative medical and physiologic therapies are not effective or toxic, when the pain and triggering is confined to the distribution of a peripherally accessible nerve branch, and when test blocks of small nerve fibers with local anesthetic solutions relieve pain.

5930 OR RF--THE SECOND FACTOR. (Eng.) Fox, J. W. (Erlanger Medical Center, Chattanooga, TN); Rapp, T. L.; Wagner, D. W. *Am J Assoc Nurse Anesth* 46(5): 501-506; 1978. (44 refs)

The chronic exposure of operating room personnel to radio frequency (RF) fields from electrosurgery units is discussed from an occupational health standpoint. The operating room personnel are chronically exposed during the use of electrosurgical devices to field strengths generally in excess of current United States guidelines and always above the Eastern bloc standards. It has been shown that the RF spectral output of an electrosurgical spark-gap and tube unit widely used in North American operating rooms extends from 1 MHz to 1 GHz, with most of the energy below 100 MHz. Power density levels along the unshielded active lead exceed 150 mW/cm² at a distance of 5 cm. Many of the effects observed during and after exposure to unscavenged anesthetic agents are similar to the complex of symptoms called radio wave sickness in the Eastern European literature. Whether an additive or potentiating effect occurs with spent anesthetics and RF is difficult to state, but it would seem likely. It is recommended that RF field strength measurements be made and recorded in the operating room during surgical procedures.

5931 THE EFFECTS OF CONTINUOUS DIRECT CURRENT ON THE GROWTH OF THE ANTLER. (Eng.) Lake, F. T. (Dept. Oral Biology/Anatomy, Sch. Dentistry, Medical Coll. Georgia, Augusta, GA 30901); Davis, R. W.; Solomon, G. C. *Am J Anat* 153(4): 625-630; 1978. (15 refs)

The effects of continuous low level direct current (DC) on the developing bone of the deer antler were studied. The DC power units were connected by electrodes to the main shaft of the right antlers. The negative electrode (cathode) was sutured from side to side through the antler tip, while the positive electrode (anode) was sutured through the skin at the base of the same antler. Power was supplied by an 8.4-V mercury battery. The deer received either 0.066, 0.5, 2.0, or 2.0 μ A of current during the entire 4-mo antler growth cycle. The application of cathodal DC over the range of 0.066-3.0 μ A to the deer antlers during their entire growth cycle caused statistically significant re-

ductions in length when compared with control antlers. Gross morphologic differences between experimental and control antlers were noted early in the experiment. The treated antlers showed abnormal branching patterns and grew in atypical directions. The data suggest that in a relatively stress-free system such as the antler the long-term application of low levels of constant cathodal DC to developing bone causes a reduction in longitudinal growth. In addition, the current may alter the normal morphology and direction of bone growth.

5932 THE ZAPPING OF AMERICA: MICROWAVES, THEIR DEADLY RISK, AND THE COVERUP (BOOK REVIEW). (Eng.) Anderson, D. M. (No affiliation given). *Bull At Sci* 34(9): 49; 1978. (1 ref)

A book entitled *The Zapping of America: Microwaves, Their Deadly Risk, and the Coverup* written by Paul Brodeur is reviewed. The author of the book cites evidence to show that man-made electromagnetic radiation is bombarding us from all sides and that it poses an awesome threat to human health. In particular, it is the capacity of microwaves to penetrate tissue and cause chromosome damage that makes their long-term effects dangerous according to the author. Also documented is a cover-up of evidence on the effects of microwaves on human beings carried out by the electronics industry and the military. Although the book "lacks coherence," it is felt that it "should not be missed."

5933 A SYSTEM FOR STUDYING EFFECTS OF MICROWAVES ON CELLS IN CULTURE. (Eng.) Chen, K.-C. (Dept. Biology, Wayne State Univ., Detroit, MI 48202); Lin, C.-J. *J Microwave Power* 13(3): 251-256; 1978. (14 refs)

An improved fluid-filled waveguide exposure chamber was used to investigate the effects of 2,450-MHz microwave radiation on Chinese hamster somatic cells in culture. The unique feature of this system is that instead of a petri dish or a flask, a 100 μ l micropipette is utilized to hold the suspension of cells. Aliquots of a suspension of Chinese hamster somatic cells from the lung of a male animal were transferred to a micropipette sample holder and were subjected to microwave irradiation at a power density of 500 mW/cm² for an exposure period of 20 min. The cytotoxic effects of radiation were assayed over a 12-day incubation period in terms of cellular growth rate, morphologic change, and clone-forming ability. The growth rate of the irradiated cells decreased by nearly 30%. Furthermore, about 10% of the irradiated cells underwent a distinct morphologic transformation within 48 hr of incubation after irradiation. With continuing incubation of the cells for up to 12 days at a temperature of 37 C, the microwave-induced transformants finally exhibited a fibroblast type of growth. The observed cellular abnormality appeared to be irreversible. Since the temperature of 37 C, which was rigidly maintained throughout the experiment (within \pm 0.1 C), is the optimal temperature for the growth of

this mammalian cell line under in vitro conditions and since an experimental temperature variance of 1 C above or below optimal did not alter the amount of morphologic difference, it is conceivable that a truly athermal influence was a contributing factor to the above observations. It may also be speculated that thermal microgradients were responsible for the observed cytotoxic effects. Further studies are needed to clarify these points.

5934 FIBROUS MUSCULAR CONTRACTURES: TREATMENT WITH A NEW DIRECT CONTACT MICROWAVE APPLICATOR OPERATING AT 915 MHZ. (Eng.) de Lateur, B. J. (Dept. Rehabilitation Medicine, RJ-30, Univ. Washington Sch. Medicine, Seattle, WA 98195); Stonebridge, J. B.; Lehmann, J. F. *Arch Phys Med Rehabil* 59(10): 488-490; 1978. (11 refs)

A new direct contact diathermy applicator operating at 915 MHz was used to treat a 61-yr-old man with bilateral contractures of the rectus femoris and brachial biceps due to 8 yr of intramuscular injection of pentazocine. The left leg, which was heated and stretched, increased in knee flexion until session 20 when a high of 127 degrees was reached. This value is within the normal range for knee flexion. The right leg, which was only stretched, did not increase in knee flexion as rapidly as the left leg. At session 20, the knee flexion for the right leg was 22 degrees less than that for the left leg. Contractures of the arms were much harder to treat. The left arm, which initially had the greatest contracture, stretched a total of only 9 degrees and had 75 degrees of residual contracture after heat and stretch treatments. This is not a functional range. The right arm had 44 degrees of contracture, and it was possible for the patient to use this arm in a reasonable fashion. Heat plus stretch seemed to relieve the contracture in the right arm more than stretch alone.

5935 USE OF MICROWAVE RADIATION IN SURGERY AND CANCER THERAPY. (Eng.) Osaka, A. (Dept. Internal Medicine, Sapporo City General Hosp., North 1, West 9, Sapporo, Japan). *J Microwave Power* 13(2): 155-161; 1978. (11 refs)

The capacity of microwaves to produce rapid protein coagulation and the potential usefulness of this fact in surgery and cancer therapy were investigated by irradiating livers in rabbit and malignant tumors in rats with 2,450-MHz microwaves. Livers of rabbits that were irradiated in vivo for about 3-4 min showed complete coagulation in the irradiated area, making resection very easy. Neither bleeding nor cholerrhagia from the cut surface of the liver was observed. When methylcholanthrene-induced spindle cell sarcomas in rats were irradiated for a period of 2 min, the tumor coagulated immediately after irradiation, and the tumor consistency became soft. The animals survived well for a long time without any symptoms until they were sacrificed for pathologic examination. In other experiments, malignant tumors after microwave irradiation could be resected with

an ordinary knife and without bleeding. Sometimes tumor recurrence was observed after irradiation; however, these animals were kept alive by re-irradiation. Of all the rats used in these experiments, 53% survived for more than 2 yr.

5936 EVALUATION OF A THERAPEUTIC DIRECT-CONTACT 915-MHZ MICROWAVE APPLICATOR FOR EFFECTIVE DEEP-TISSUE HEATING IN HUMANS. (Eng.) Lehmann, J. F. (Dept. Rehabilitation Medicine, Univ. Washington Sch. Medicine, Seattle, WA 98195); Guy, A. W.; Stonebridge, J. B.; deLateur, B. J. *IEEE Trans Microwave Theory Tech* 26(8): 556-563; 1978. (24 refs)

A 13-cm square direct-contact 915-MHz microwave applicator with stripline feed was evaluated to determine the temperature distributions produced in tissue models and in the anterior thigh of human volunteers. From the experiments with tissue models, it was concluded that the applicator produces significant heating within the musculature, that a radome is necessary to prevent hot spots in the superficial tissues, and that air cooling is necessary to prevent excessive heating of superficial tissues. The applicator was then tested on human volunteers that were divided into two groups, the first having an anterior thigh fat layer of 1 cm or less and the second having a fat layer of 2 cm or greater. The subjects were irradiated with the radome in place with and without cooling. When cooling was not used, none of the subjects could tolerate a planned 20-min exposure. With the radome and forced-air cooling, the applicator was found to selectively elevate temperatures in the muscles (1-2 cm depth) to 43-45 C. It also appeared that by increasing power levels after blood flow has cooled this tissue it may be feasible to push these temperatures back to 43-45 C and hold them at these levels for longer periods of treatment. The possibility exists, therefore, for using this applicator to heat cancerous tumors in muscle. A comparison of calculations of the specific absorption rate in human thighs with those in models indicated that the models are highly reliable predictors of temperature distributions produced in human tissues.

5937 EFFECT OF ELECTROSTATIC FIELDS ON THE CHROMOSOMES OF EHRlich ASCITES TUMOR CELLS EXPOSED IN VIVO. (Eng.) Mitchell, J. T. (Dept. Biology, Colgate Univ., Hamilton, NY 13346); Marino, A. A.; Berger, T. J.; Becker, R. O. *Physiol Chem Phys* 10(1): 79-85; 1978. (13 refs)

Mature female Swiss Ha/ICR mice bearing Ehrlich ascites tumor were exposed to vertical or horizontal electrostatic fields in the range of 80-160 V/cm over periods ranging from 2-15 wk to investigate the effect of such fields on tumor cell chromosome aberrations. Cells exposed to horizontal electrostatic fields for 2 wk had a significantly (at the 0.5% level) greater percentage of cells with abnormal chromosomes ($22.5 \pm 6.6\%$) than did control cells ($8.8 \pm 7.1\%$) or cells exposed

to vertical fields for 2 wk ($5.8 \pm 5.8\%$). The most numerous chromosomal abnormalities detected were chromatid exchanges (translocations) and isochromatid breaks. Extended exposure times of 4-15 wk resulted in the disappearance of aberrant chromosomes, suggesting that the affected cells were incapable of cellular replication resulting eventually in their disappearance via cell death. It is believed that the reported results are the first qualitative and systematic description of electrostatic field-induced effects at the chromosomal level, and it is suggested that the production of chromosomal abnormalities in tumor cells in mice following exposure to low strength electrostatic fields reinforces the proposal of electrostatic field-induced trigger phenomena in biologic systems.

5938 PROPOSED EXPOSURE LIMITS FOR MICROWAVE AND RADIOFREQUENCY RADIATIONS IN CANADA.

(Eng.) Repacholi, M. H. (Non-Ionizing Radiation Section, Consumer and Clinical Radiation Hazards Div., Radiation Protection Bureau, Health and Welfare Canada, Ottawa, Ontario, Canada). *J Microwave Power* 13(2): 199-211; 1978. (51 refs)

Proposed exposure limits for microwave and radio frequency radiations in Canada are discussed. The Canadian Standards Association recommends a maximum permissible level (MPL) of exposure, which is similar to that of the American National Standards Institute, a maximum power density of 10 mW/cm^2 for continuous exposure to microwaves. This recommended standard applies to the frequency range of 10 MHz to 100 GHz. The Federal Department of Health and Welfare, which does not presently have a recommendation for open-beam exposure to microwave and radio frequency radiation, is considering the following limits. For any person exposed to microwave and radio frequency radiation, either continuous wave or pulsed, the following values should not be exceeded during any 1-hr period: an averaged energy flux of 1 mW/hr/cm^2 , an averaged power density of 1 mW/cm^2 , a root mean square (RMS) electric field strength of 60 V/m, an RMS magnetic field strength of 0.16 A/m, and an averaged (over 1 min) maximum power density of 25 mW/cm^2 . The frequency range to which this recommendation applies is 10 MHz to 300 GHz. The proposal does not apply to deliberate medical exposure of patients to such radiation. This proposal has been modified slightly in that a ten-fold safety factor for exposure of the general public has been dropped. It is felt that present data on the biologic effects of microwave and radio frequency radiation do not justify a lower MPL. A 1 mW/hr/cm^2 MPL for general exposure, lying between the 10 mW/cm^2 value in the United States and the Russian value of 0.01 mW/cm^2 , is proposed for the following reasons. The 10 mW/cm^2 value appears to be inadequate even on the assumption that only thermal effects pose a hazard. There are animal and human phantom data that indicate that localized heating may produce adverse effects from exposure at power densities of 10 mW/cm^2 and lower at frequencies generally below 500 MHz. The Soviet standard

appears to be too strict (based on zero risk), and so-called nonthermal effects at low power densities have not been confirmed in the West.

5939 BIOELECTROCHEMICAL STUDIES OF IMPLANTABLE BONE STIMULATION ELECTRODES. (Eng.)

Spadaro, J. A. (Dept. Orthopedic Surgery, Upstate Medical Center, Syracuse, NY 13210). *Bioelectrochem Bioenerget* 5: 232-238; 1978. (5 refs)

Cultured mouse bone marrow cells and fibroblasts were exposed to several metal cathodes in vitro to investigate the mechanism of electrically stimulated osteogenesis. Bone marrow cells were exposed to silver, platinum, gold, titanium, stainless steel 316L, and graphite cathodes carrying a constant current ranging from 0.5-20 μA , applied over a 4-hr period at 37 C. Most changes in cell populations were relatively independent of the current level over the above range. Both cell-specific and electrode-specific changes were observed near the electrodes. Five of the six cathodes produced a depression in neutrophil population. Lysis was elevated around the stainless steel, platinum, and possibly graphite cathodes. An extraordinary increase in eosinophilic cells was noted near the platinum cathode and anode. In a similar experiment, mouse fibroblasts were exposed to the same cathodes at a constant current of 2 μA , which was applied for 4 hr. These fibroblasts were generally insensitive to all of the cathodes, and it is concluded that fibroblasts do not seem to be unfavorably affected by these cathodes at this modest current density. When the current-potential behavior was measured for a number of implantable metals and alloys in a biologic medium, oxygen reduction was observed in the range reported for the successful bone stimulation around cathodes. This raises the possibility that the products of oxygen reduction may influence cells in the bone marrow or nearby tissues to begin the production or elaboration of bone. If the reduction of oxygen is an important factor in electrical bone formation, then it seems that the platinum electrode would be an efficient choice, providing the reactions observed in the bone marrow experiments are not detrimental to the tissues. Gold or silver might be logical alternative materials in that case.

5940 LANTHANUM INHIBITION OF ELECTRICALLY INDUCED DEDIFFERENTIATION IN FROG ERYTHROCYTES. (Eng.) Smith, S. D. (Dept. Anatomy, Univ. Kentucky Coll. Medicine, Lexington, KY 40506); Thomas, C. L.; Frasch, S. F. *Bioelectrochem Bioenerget* 5: 177-184; 1978. (11 refs)

Lanthanum inhibition of electrically induced dedifferentiation in frog (*Rana pipiens*) erythrocytes was studied to investigate whether blockade of divalent calcium transmembrane passage can in turn block dedifferentiation. Erythrocytes from adult northern grassfrogs were diluted in isotonic saline and isotonic calcium-magnesium-free phosphate buffered saline. When these cells were subjected to 100

mV square pulses at a frequency of 50 Hz (10 msec on and 10 msec off) over a period of 1 hr, they exhibited dedifferentiation in both media. When lanthanum chloride was added at concentrations of 10^{-4} molar or larger, transformation was effectively blocked. At concentrations of 10^{-5} molar or less, inhibition was minimal. Cellular dedifferentiation was also produced by adding 10^{-6} molar calcium ionophore A23187. When lanthanum chloride at a concentration of 10^{-4} molar was added to a culture containing 10^{-6} molar ionophore, transformation was blocked. The imposition of current reversed the blockage once more, allowing the cells to transform as though neither ionophore nor lanthanum chloride were present. It is concluded that transmembrane exchange of divalent calcium is a critical step in electrically induced dedifferentiation of these cells.

- 5941 COMBINED MICROWAVE THERAPY. (Eng.)
Nelson, A. J. M. (21 McCourt St.,
Leederville, West Australia 6007); Holt, J. A. G.
Med J Aust 2(3): 88-90; 1978. (11 refs)

The results of using 434-MHz radiowave hyperthermia in combination with cobalt radiotherapy and/or radioactive gold implants for the treatment of 52 patients with advanced head and neck cancer are reported. These results are also compared with those obtained in comparable series of patients receiving cobalt radiotherapy with hyperbaric oxygen (HBO) or conventional supervoltage therapy (SVT). The rise in temperature in the tumors was measured with a specially designed thermocouple probe. A temperature of up to 42.5 C was recorded at the end of 434-MHz hyperthermic treatment. Complete healing and disappearance of the tumor masses occurred after combined radiotherapy and hyperthermia in 94% of the patients compared with 62.5% for HBO-treated patients and 36.5% for SVT-treated patients. At 3 yr after treatment, the cumulative percentage of cases not having had persistent or recurrent local disease was 60% for patients treated with combined radiotherapy and hyperthermia compared with 23% for HBO-treated patients and 8% for SVT-treated patients. The 3-yr survivals for patients treated by combined radiotherapy plus hyperthermia, HBO therapy, or SVT were 54, 29, and 19%, respectively.

- 5942 REGENERATION IN DENERVATED LIMBS OF
SALAMANDERS AFTER INDUCTION BY APPLIED
DIRECT CURRENTS. (Eng.) Rose, S. M. (34 High
St., Woods Hole, MA 02543). *Bioelectrochem Bio-
energet* 5: 88-96; 1978. (33 refs)

Denervated stumps of the salamander *Triturus viridescens* received the same patterns of electricity as those observed in naturally regenerating limbs with nerves to investigate whether nerves support limb regeneration by controlling the bioelectric pattern. The tip of the stump was made either 20-30 mV positive or 20-30 mV negative to points on the skin just distal to a circular platinum contact that was placed around the stump 2-3 mm from the tip. When the tips of stumps were made

20-30 mV negative to the circular locus on the skin just distal to the circular contact, an electrical gradient was established that was similar in magnitude, sign, and length to the electrical gradient in limbs producing blastemas naturally. When three denervated stumps were made 20-30 mV negative at their tips twice for 2 hr at a time during each of 3 consecutive days, signs of regeneration appeared after only a 12-hr period with the tips negative plus an additional 24-hr period of no stimulation at 23 C. None of 15 denervated stumps made positive at the tip nor any of 10 denervated control stumps showed any signs of regeneration. In the stumps that showed regeneration, the beginning of a loss of old tissue structure was also observed, and some cells showed condensation of their chromosomes. It appeared that a primary action of nerves in regeneration was being replaced by the polarized current after only 12 hr of treatment. Continuation of treatments for 4 hr/day for more than 3 days caused greater than normal loss of structure in the soft tissues and some loss of bony matrix. To prevent excessive loss of structure, some tips were made positive during treatments for a few days, then negative, and then positive again. Three stumps treated in this way were allowed to regenerate to the fingerbud stage.

- 5943 REGIONAL LEVELS OF HISTAMINE IN RAT
BRAIN AFTER MICROWAVE IRRADIATION:
EVIDENCE FOR ARTIFACTS IN THE ENZYMIC-ISOTOPIC
ASSAY. (Eng.) Subramanian, N. (Institut fuer
Pharmakologie und Toxikologie der Universitat
Erlangen-Nuernberg, Universitaetsstrasse 22, D-8520
Erlangen, W. Germany); Schinzel, W.; Mitznegg, P.;
Estler, C.-J. *Agents Actions* 8(5): 488-490; 1978.
(12 refs)

Regional levels of histamine in the rat brain after microwave irradiation and after decapitation were measured by two different analytic techniques. Male Wistar rats that were maintained in a 12-hr dark-light cycle with water and standard diet available ad libitum were either decapitated or subjected to whole body microwave irradiation (4,900 W for 40 sec). Histamine levels in various regions of rat brain that were measured fluorimetrically were similar for rats killed by decapitation and microwave irradiation. However, when histamine was determined by an enzymatic-isotopic method, the histamine levels were 5-20 times higher after microwave irradiation than after decapitation. To test the possibility that an artifact was formed during microwave irradiation that interferes with the enzymatic-isotopic assay, the chloroform extracts prepared from whole brain homogenates were cochromatographed with standard methylhistamine. An examination of the radioactivity profile of a thin layer chromatogram of methylated products in the enzymatic-isotopic assay of histamine revealed that for decapitated rats only one peak existed, which corresponded to the standard methylhistamine. In contrast, microwave irradiation resulted in three peaks in the assay, corresponding to standard methylhistamine and two other unknown compounds.

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This explains the falsely elevated histamine levels estimated by the enzymatic method. It is concluded that the combination of microwave irradiation and the enzymatic-isotopic assay yields erroneous results in the histamine analysis and that this procedure should be avoided.

- 5944 APPLICATION OF HIGH-POWERED MICROWAVE IRRADIATION FOR ACETYLCHOLINE ANALYSIS IN MOUSE BRAIN. (Eng.) Fujiwara, M. (Div. Neurochemistry, Inst. for Neurobiology, Okayama Univ. Medical Sch., 2-5-1 Shikata-cho, 700 Okayama, Japan); Watanabe, Y.; Katayama, Y.; Shirakabe, Y. *Eur J Pharmacol* 51(3): 299-301; 1978. (7 refs)

Acetylcholine levels are studied in whole brains and discrete areas of brains of mice sacrificed by decapitation, conventional microwave irradiation, or by high-power short-duration microwave irradiation. Microwave irradiation was performed using either the conventional method of delivering 1.3 kW of 2,450-MHz radiation for 2.0 sec or a new method by which 3.0 kW of 2,450-MHz radiation was delivered for 0.2 sec. Acetylcholine levels in whole brains homogenized within 1 and 2 min after decapitation were 21.6 ± 1.1 nmole/g tissue and 15.3 ± 0.7 nmole/g tissue, respectively. After high power microwave irradiation the acetylcholine level for the whole brain was 49.3 ± 2.4 nmole/g tissue compared with only 25.7 ± 1.4 nmole/g tissue after conventional microwave irradiation. Regional differences in acetylcholine levels in the brain were maintained when high-power microwave irradiation was used. Compared with conventional methods, these levels ranged from 1.5 times higher in the brain stem to 1.9 times higher in the diencephalon. Acetylcholine levels in both whole brains and discrete areas of brains varied according to the time required to inactivate the enzymes. The more rapid the inactivation, the higher the acetylcholine level. It is suggested that high-power short-duration microwave irradiation could result in more accurate acetylcholine measurements than does conventional microwave irradiation.

- 5945 ATTENUATION OF ELECTROMAGNETIC RADIATION FROM MICROWAVE OVENS BY MAGNETIC RESISTIVE SHEETS. (Eng.) Ramasamy, S. R. (Defence Electronics Res. Lab., Chandrayanagutta Lines, Hyderabad 500 005, India). *J Inst Electron Telecommun Eng* 24(7): 305-306; 1978. (4 refs)

The use of magnetic resistive sheets (MRS) to reduce leakage radiation from microwave ovens is discussed from a theoretic standpoint. The MRS consists of rubber ferrite sheets backed by a metal plate and situated at the peripheral edges of the microwave cooker door. It is calculated that the attenuation of leakage radiation by MRS is expected to be only 10-12 dB when the door gap is between 0.5 and 1.0 mm. However, a much higher order of attenuation is expected if the MRS were arranged in the form of a corrugated structure because of its inherent attenuating

nature. Since rubber is kneaded with ferrite and the weight ratio is 1:4, no adverse effect due to the rubber on the food contents of the oven is expected.

- 5946 ACUTE MICROWAVE IRRADIATION AND CATARACT FORMATION IN RABBITS AND MONKEYS. (Eng.) Kramar, P. (Dept. Ophthalmology RJ-10, Sch. Medicine, Univ. Washington, Seattle, WA 98195); Harris, C.; Emery, A. F.; Guy, A. W. *J Microwave Power* 13(3): 239-249; 1978. (13 refs)

Specific absorption rate (SAR) patterns and cataractogenic thresholds for rabbits and monkeys irradiated in the near field of a cavity-backed 2,450-MHz resonant slot radiator in a ground plane were studied to simulate the effects of microwave oven door leakage. Both immediate and delayed effects were noted in the irradiated eyes of the rabbits. Among the immediate effects were tearing, a constricted pupil, dilated conjunctival and iris vessels, a turbid anterior chamber, and a milky band in the posterior cortex of the lens. The delayed effects were confined to the lens and were seen 5-7 days after irradiation. These changes consisted of vacuole formation along the posterior suture line, followed by progressive opacification of the posterior cortex. The lowest incident power-time level at which the lens showed any change was 180 mW/cm^2 for 140 min. Although monkeys exposed to up to 500 mW/cm^2 for 60 min sustained facial burns, no lens damage was observed. These results were substantiated by computer thermal models. The good agreement between the measured and the computed temperature fields found in these experimental animals suggests that it is possible to predict the ocular temperatures and cataractogenic thresholds for man, if the blood flows and the SAR patterns are known.

- 5947 MICROWAVE POWER APPLICATIONS IN JAPAN. (Eng.) Kase, Y. (Range Div., Sharp Corp., Hirano, Osaka, Japan); Ogura, K. *J Microwave Power* 13(2): 115-123; 1978. (14 refs)

Domestic, industrial, scientific, and medical microwave power applications in Japan are reviewed. On the domestic scene, a gradual expansion of the microwave cooking oven market occurred after late 1971; however, sales have declined since the 1974 peak volume. The output power for most domestic microwave ovens is 600 W. A microwave leakage regulation became effective on December 31, 1970. Although power leakage is stipulated for microwave ovens by the Electrical Appliance and Material Control Law, no regulation has been provided for industrial equipment. Therefore, each equipment manufacturer has to set their own standard referring to the 5 mW/cm^2 standard for microwave ovens. The principal application fields of industrial microwave heating are food processing, insect killing, film and paper processing, and tire and rubber processing. Most of the microwave heating systems currently installed are in the food industry and typically consist of an oven-conveyor combination. Magnetrons are usually used as mic-

rowave power sources, and output power levels of 1.4 kW or 5 kW at 2,450 MHz and 30 kW at 915 MHz are typical. Examples of low power applications include a moisture meter, intrusion alarms, and automatic door sensors, which operate in the X-band. Biomedical applications include microwave heating for arthritis and rheumatism, the joint use of microwave power and X-rays in the treatment of malignant tumors, and microwave-induced enzyme inactivation in the brains of small animals.

- 5948 STUDY OF ELECTROKINETIC PROPERTIES OF BLOOD FORMED ELEMENTS UNDER THE ACTION OF ELECTROMAGNETIC FACTORS. (Rus.) Arsent'ev, Iu. V. (Dept. Normal Physiology, Chita Medical Inst., Chita, USSR); Arsent'eva, T. V. *Probl Geriatol Pereliv Krovi* 23(8): 25-28; 1978. (12 refs)

The effects of electromagnetic fields of different frequency and intensity on the electrophoretic mobility (EPM) of erythrocytes and thrombocytes of dogs and human donors were studied in vitro, using cell suspensions in physiologic saline solution (about 100 cells/mm³). Exposure to electromagnetic fields with 10-200 Hz frequency and 200 Oe field intensity for 5-60 min caused no significant changes in the EPM of the erythrocytes and thrombocytes of dogs. Human thrombocytes were exposed to electromagnetic fields with a radiation energy of 20-150 W and a frequency of 2,375 MHz for 45 sec. The exposure caused energy-dependent decrease in the EPM of the thrombocytes: the EPM was 1,100 μ /sec/W/cm following exposure to a 20-W field, 1,074 μ /sec/W/cm following exposure to a 75-W field, and 1,021 μ /sec/W/cm following exposure to the 150-W field, versus 1,140 μ /sec/W/cm in the non-irradiated control. The difference from the control became statistically significant at the $p < 0.01$ level at a radiation energy of 75 W. The results are interpreted as a global effect determined by the competition between the structural reconstruction of the membranes and sorption of blood plasma proteins on their surface.

- 5949 DIFFERENTIATION OF BONE MARROW LEUKOCYTES OF ALBINO RATS UNDER THE EFFECT OF SUPER-HIGH-FREQUENCY ELECTROMAGNETIC FIELD. (Rus.) Obukhan, E. I. (Biology and Hygiene Res. Lab., A. N. Marzhev Scientific Res. Inst. General and Communal Hygiene, Kiev, USSR); Belokrinitskii, V. S. *Viroh Delo* (6): 120-124; 1978. (9 refs)

The effect of whole-body exposure to electromagnetic field (2,375 MHz) on the differentiation of bone marrow leukocytes was studied in 40 male and female adult albino rats; 14 others served as nonirradiated controls. One group was exposed to an electromagnetic field with 500- μ W/cm² intensity for 6 hr; the second group was exposed to a 50- μ W/cm² field 6 hr/day for 10 consecutive days. Destruction of the majority of the cells of the granulopoietic series (pyknosis, chromatinolysis, nucleolysis, and cytolysis), vacuolization, hemorrhages in the bone marrow, marked hypoplasia and predominance of erythrocytes over myelokaryocytes, significant in-

crease in the eosinophil count among the myelocytes, and less frequently, among the metamyelocytes, increased functional activity of granulocytes, hypersegmentation of the nuclei of the neutrophil granulocytes, dissociation in the rates of maturation of the nucleus and cytoplasm, and "young" myelocytes were seen 16-72 hr after the single-time exposure. Similar but less intense changes were seen in the hemorrhagic regions of the bone marrow of the rats exposed to the 50- μ W/cm² field 10 times. In the nonhemorrhagic zones, there were only few deformed cells and numerous hypertrophied, slightly differentiated, granulocytes. The findings indicate the adaptation and regeneration of the leukocytes during fractionated exposure.

- 5950 INDUCTION OF CHROMOSOME ABERRATIONS IN PLANTS IN A CONSTANT MAGNETIC FIELD. (Rus.) Shevchenko, V. V. (N. K. Koltsov Inst. Developmental Biology, USSR Acad. Sciences, Moscow, USSR); Grinikh, L. I.; Strekova, V. Yu. *Genetika* 14(6): 1101-1103; 1978. (3 refs)

The cytogenetic effect of a constant electromagnetic field (9 or 12 kOe, gradient 200-400 Oe) on germinating seeds of *Crepis capillaris* was studied. In the first experiment, the seeds were germinated for 2 days in a colchicine solution (0.01%) while being exposed to the electromagnetic field. In the second experiment, air-dried seeds were exposed to the magnetic field for 2 mo before germination in colchicine solution (0.01%). The magnetic field induced no chromosome aberrations in the root tip meristem cells in either experiment.

- 5951 THE NUMBER OF MICROWAVE RADIATION SOURCES INCREASES BY 15% ANNUALLY. IS MICROWAVE RADIATION AN INVISIBLE HAZARD? (Dut.) Anonymous *IT (Procestechniek) Aktuell* (31/32): 7; 1978. (0 refs)

The general problems of the health hazards of microwave radiation are discussed in light of the increasing use of microwave ovens. Aside from the direct or thermal effects, microwave radiations, especially small doses, are claimed to modify human behavior by causing asthenia syndrome (apathy, laxity, inability to concentrate, sleeplessness). The biologic effect of microwave radiation is dependent on the energy, frequency, and duration of exposure.

- 5952 MAGNETIC PROPERTIES OF BIOLOGICAL MEMBRANES. (Ukr.) Kadnikov, O. G. (Kharkov State Univ., Kharkov, USSR); Zaliubovskii, I. I.; Iakovlev, O. V. *Dopov Akad Nauk Ukr* 13(6): 550-554; 1978. (13 refs)

Studies on the magnetic properties of biologic membranes and on the effects of magnetic fields on such membranes are reviewed. It has been demonstrated that the free radical peroxidation of membrane lipids is one of the processes that determines the magnetic properties of biologic membranes. In one experiment, the white substance of the brain

of bulls was exposed *in vitro* to a magnetic field (9 kOe) for 2 hr. The spectrophotometric study of the lipid membranes in the wavelength range of 3,200-3,500 cm^{-1} demonstrated an increase in the absorption of the exposed specimens compared with the nonirradiated controls before the increase in the total hydroperoxide concentration. The investigation of the individual fractions (cardiolipin, sphingomyelin, lecithin, and phosphatidylethanolamine) revealed that the change in the concentration was caused mainly by lecithin.

- 5953 TEMPERATURE REACTIONS AND SURVIVAL OF EXPERIMENTAL ANIMALS AFTER EXPOSURE TO MICROWAVES OF VARIOUS INTENSITY. (Rus.) Matrenina, V. L. (Scientific Res. Inst. Medical Radiology, Obninsk, USSR); Posadskaya, V. M.; Rudakov, I. A. *Biull Eksp Biol Med* 86(9): 282-285; 1978. (6 refs)

The effect of whole-body exposure to microwave radiation (2,375 MHz, energy density 10, 40, and 60 mW/cm^2 , length of exposure 10, 30, 45, and 60 min) on the rectal temperature and survival of 48 adult CBA mice and of 26 Wistar rats was studied. Irradiation at 40 mW/cm^2 caused restlessness, then asthenia, hyperemia of the ears, tail, paws, and nasal discharge in the rats. Compared with the initial values, the rectal temperature in the rats rose by 2.1 C during the irradiation, but it was reduced by 0.5-1.3 C between 3 hr and 5 days after exposure. Irradiation of the mice at 40 mW/cm^2 caused only insignificant hyperthermia during exposure, but the rectal temperature dropped subsequently to 29.2-35.4 C. Exposure to 10 and 40 mW/cm^2 for 10 min caused no deaths among the mice, but 8 of the 24 mice irradiated at 40 mW/cm^2 for 30 min died: 2 died during the irradiation, 3 on day one, 2 on day two, and one on day 19 after exposure. Exposure to 40 mW/cm^2 for 30 min caused the death of 2/8 rats on days 19 and 23, respectively. Exposure to 40 mW/cm^2 for 60 min caused the death of 9/10 rats: 4 died during the irradiation, 2 on day one, and one each on days 21, 25, and 30 after exposure, respectively. Irradiation at 10 mW/cm^2 caused no significant change in the rectal temperature or the mortality of the animals. Further studies will be necessary to elucidate the causes of the late death of the animals.

- 5954 HIGH TENSION (LETTER TO EDITOR). (Eng.) Miller, M. W. (The Univ. Rochester, Rochester, NY); Kaufman, G. E.; Carstensen, E. L.; Becker, R. O.; Marino, A. A. *Sciences* 18(8): 2-3, 27; 1978. (3 refs)

Opposing views concerning the hazards of extremely low frequency radiation generated by high tension power transmission lines are presented. On the one hand, claims that the electric and magnetic fields from high tension lines cause biologic effects appear to be without basis and that no one has identified a single effect that will occur from direct exposure to a transmission line's electric or magnetic field. The general conclusion from investigations on the growth and development of plants and animals, on the cellular and molec-

ular aspects of metabolism, on cell physiology, on whether or not there are alterations in behavior, on the health of people living near transmission lines, and on the health of utility line-men working for a period of 9 yr on energized 345,000- and 765,000-V transmission lines is that there is an absence of biologic effects from field levels comparable to those experienced by persons or other living objects underneath an operational 765,000-V transmission line. On the other hand, it is claimed that such electrical environments have been shown to cause biologic effects in test animals, including human beings, in more than 70 independent investigations conducted throughout the West. Numerous additional studies within the Soviet Union have also demonstrated that transmission line fields cause adverse biologic effects in humans and animals. It is claimed that living or working near high-voltage transmission lines constitutes human experimentation because many independent studies indicate that there is a risk, even though the specific effects of the exposure cannot be pinpointed. Examples are cited of the effects of electric and magnetic fields on human serum triglyceride levels, the appearance of bone tumors in rats, the growth pattern of flatworms, human reaction time, human biorhythms, and growth stunting in mice.

- 5955 VISUAL DISPLAY UNITS—ARE THEY SAFE? (Eng.) Gilbert, P. (Post Office Telecommunications, Occupational Health Service, London, England). *Occup Health* 30(8): 357-362; 1978. (8 refs)

Potential health hazards of visual display units (VDU) are discussed. Large numbers of VDUs have been monitored for both ionizing and nonionizing radiation with no detectable results for each category. Since the refresh rate of the modern VDU screen is at least 50 Hz, as opposed to approximately 25 Hz for domestic television sets, the likelihood of flicker-induced photic fits in susceptible subjects is extremely remote. Although a wide range of subjective or psychologic symptoms have been reported in association with viewing VDU screens (tiredness, headaches, giddiness, nausea, irritability, anxiety, and depression), there is no evidence to link the incidence of these symptoms directly with viewing the VDU screen. It is concluded that at present there is no objective evidence that working with VDUs constitutes a health hazard, although the ergonomic factors of the total work situation merit continuing attention.

- 5956 MICROWAVE-INDUCED HYPERTHERMIA DOSE DEFINITION. (Eng.) Atkinson, E. R. (Div. Cancer Treatment, Natl. Cancer Inst., Bethesda, MD 20014). *IEEE Trans Microwave Theory Tech* 26(8): 595-598; 1978. (17 refs)

A hyperthermal dose-unit definition is proposed. It is suggested that the simple short-term reaction kinetics of cell viability as a function of time and temperature be employed to quantitate hyper-

thermal dosage. In order to arrive at a dosage figure by this means, it is merely necessary to interpret the time and temperature measurements which are already ordinarily monitored in clinical hyperthermia in terms of the nonlinear reaction kinetics of tissue viability. The hyperthermal dose-unit definition amounts simply to incorporating a nonlinear weighting factor in the procedure already in use for computing hyperthermal exposure in degree hours above an arbitrary temperature. It may be loosely interpreted as the percentage of cells killed by such a treatment applied to in vitro tissue culture. The dose defined will not in general be linearly cumulative over times comparable to cell cycle duration and will be strictly interpretable as a surviving fraction only for the cell subpopulation and under the growth conditions for which the numeric values of cytotoxicity are determined. As an example of the clinical applicability of the hyperthermal dose definition, the rectal temperature profile of two patients receiving whole body hyperthermia may be taken as equivalent to a hyperthermal exposure to 42.0 C for 30 min or to 41.8 C for 50 min, since both of these conditions produce a dose of about 20 units.

- 5957 EFFECT OF ELECTROMAGNETIC WAVES IN THE MILLIMETER RANGE (8.2 MM) ON THE VIABILITY OF BAKER'S YEAST. (Rus.) Abramova, N. V. (Kishinev, USSR); Makeev, Iu. V.; Tenn, F. A. *Elektron Obrab Mater* (2): 74-75; 1978. (7 refs)

The effect of exposure to electromagnetic field (wavelength 8.2 mm, intensity 1 mW/cm², length of exposure 10, 20, or 30 min) on the viability of *Saccharomyces cerevisiae* strain 14 in beer-wort was studied at 29 C. The viability was determined from the number of colonies growing in wort agar after irradiation. Compared with the untreated control, exposure caused a 20% decrease in the viability (number of colonies). There was no significant difference in the reduction as a function of the length of exposure.

- 5958 ENHANCED EFFECT OF RADIOTHERAPY FOR MALIGNANT TUMORS BY SUPER-HIGH-FREQUENCY HYPERTHERMIA. (Rus.) Aleksandrov, N. N. (Scientific Res. Inst. Oncology and Medical Radiology, Belorussian SSR Ministry of Health, Minsk, USSR); Fradkin, S. Z.; Zhavrid, E. A.; Muravskaja, G. V.; Malinovskii, G. V.; et al. *Vopr Onkol* 24(8): 14-19; 1978. (8 refs)

The enhancement of the effect of radiotherapy by means of local super-high-frequency (SHF) hyperthermia was studied in 105 mice with solid Ehrlich's tumor, 500 rats with sarcoma-45, and 145 patients (31 men, 114 women, aged 10-70+ yr) with malignant tumors (skin melanoma, synovialoma, angiosarcoma, fibrosarcoma, breast cancer, and other tumors). The animals received telecobalt treatment (dose rate 125 R/min) 5 min to 72 hr after local hyperthermia (41.5 C, wavelength 12.6 cm, duration 30-60 min). The inhibition of tumor growth was about 150% greater than in animals receiving lon-

izing radiation only. The mean survival time was 50.6 ± 2.9 days after hyperthermia and radiotherapy, 42.8 ± 2.6 days after ionizing irradiation, and 38.6 ± 2 days after exclusive hyperthermia. The enhancing effect of hyperthermia was strongest when it was followed immediately by radiotherapy. In the human patients, hyperthermia (42 C) was generated by electromagnetic field (wavelength 2,450 ± 49 MHz for superficial tumors, 460 MHz for deep tumors; duration 60-120 min), and it was followed immediately by radiotherapy. Twelve patients received hyperthermic treatment alone before surgery; six of these achieved complete remission, four others 25-30% remission. Hyperthermia was combined with radiotherapy in 133 patients. Complete disappearance of tumor cells, and necrosis was seen in 36 patients, marked destructive changes and subtotal necrosis in 75, but there were no marked changes in 22. The findings indicate the marked radiosensitizing effect of SHF hyperthermia in cancer therapy.

- 5959 BILATERAL TESTICULAR ATROPHY FOLLOWING ACCIDENTAL DIRECT RADAR BEAM EXPOSURE. (Ger.) Iking, U. (Urologische Abteilung des Chirurgischen Zentrums, Universität Heidelberg, Neuenheimer Feld, D-6900 Heidelberg 1, W. Germany); Palmtag, H.; Mohring, K.; Wurster, K. *Aktuel Urol* 9(4): 221-224; 1978. (7 refs)

A 36-yr-old man developed marked bilateral testicular atrophy 1-2 yr after accidental exposure of the genitals to radar waves (300 W, pulse power 10 kW). During a 15-min repair of radar equipment, the patient's genitals were at the height of and a few centimeters from the emitter, which he thought was turned off. Fourteen days after exposure, the patient developed painful reddening of the scrotal skin; however, symptoms disappeared within days. One year after exposure, he noticed a lessening in volume of the right testicle and the following year a decrease in the left testicle. Three yrs after exposure, the patient underwent testosterone therapy (280 mg/mo). Nine yr postexposure, investigations of biopsy specimens showed shrinkage of the seminiferous tubules with broadening of the lamina propria, marked hyperplasia of the elastic fibers, thickening and hyalinization of the basal membranes, the absence of mature sperm, foci of Leydig's cell hyperplasia, intimal fibrosis, and hyalinosis of the small vessels. It was concluded that the histology of the testicular material demonstrated the same damage after radar exposure as that seen after therapeutic x-irradiation.

- 5960 RESPONSE OF INSULATED ELECTRIC FIELD PROBES IN FINITE HETEROGENEOUS BIOLOGICAL BODIES. (Eng.) Mousavinezhad, S. H. (Sch. Engineering, Ferdowsi Univ., Mashhad, Iran); Chen, K.-M.; Nyquist, D. P. *IEEE Trans Microwave Theory Tech* 26(8): 599-607; 1978. (16 refs)

An idealized spherical metallic probe insulated by a dielectric layer and immersed in a finite lossy-dielectric biologic body was studied to demonstrate

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that location-dependent probe parameter variations can be reduced by insulating the metallic probe with a thick coating of low-permittivity dielectric. This type of probe was demonstrated both analytically and experimentally to have a relatively constant calibration factor. The effective diameter and equivalent impedance of the spherical probe become relatively independent of finite size and electrical parameters of the body in which it is immersed when the insulation-to-probe diameter ratio exceeds 1.5 with an insulation having a dielectric constant of about 2.0. Agreement of actual measurements for the field distribution in a simulated finite biologic body, obtained using such an insulated probe, with theoretic predictions confirmed this conclusion. Since the main findings of this study were rather geometry independent, it appears that the results of the present study can be applied to systems without spherical symmetry; this point was verified experimentally. The main advantages of using an implantable electric field probe over a temperature probe are its capability of measuring a low induced field and its ability of measuring each component of the induced electric field separately. However, it also had disadvantages, such as, the limitation of using it in regions with low dielectric constants and the difficulty of designing an interference-free lead wire system for the probe.

- 5961 COHERENT ELECTRIC VIBRATIONS IN BIOLOGICAL SYSTEMS AND THE CANCER PROBLEM. (Eng.) Froehlich, H. (Dept. Physics, Oliver Lodge Lab., The Univ., P.O. Box 147, Liverpool L69 3BX, England). *IEEE Trans Microwave Theory Tech* 26(8): 613-617; 1978. (18 refs)

Theoretic and experimental evidence for the existence of coherent electric vibrations in biologic systems is reviewed in relation to the control of cancer. Evidence for the biologic importance of vibrations in the region of 5×10^{10} Hz has been obtained from experiments with coherent millimeter waves. For example, in one experiment yeast was suspended in a stirred aqueous nutrient medium and exposed to a frequency range of between 4.14 and 4.19×10^{10} Hz. The results showed five minima with growth rates between 70 and 85% of controls within 4.65 and 4.79×10^{10} Hz, separated by maxima of rates between 100 and 115% of controls, and no noticeable effect outside this range. Thus, the effect was largely negative and exhibited extremely sharp biologic frequency resonances. These findings strongly support the conjecture that coherent electric vibrations play an important role in biologic activities. The strongest evidence for the biologic importance of vibrations obtained from Raman effect experiments with bacterial cells has been observed at a frequency of about 3×10^{12} Hz, although the effect may extend to lower frequencies, possibly to about 10^{11} Hz. A model calculation is presented to support the proposal of coherent excitation of electric vibrations (polarization waves) through supply of metabolic energy. With regard to the control of cell division in normal tissue, which is absent in cancer, it is shown that in principle this control could rest on the

coherent electric vibrations discussed above. If the range of millimeter waves is relevant to the control of tissue growth and if this relevance shows resonant effects similar to those discussed above, then important nonthermal effects of millimeter waves of correct frequencies on cancer tissues should be expected. Recently the existence of several Raman lines in the region of 50 - 200 cm^{-1} has been demonstrated, and these were found to be broadened and split in the case of mammary carcinoma. If confirmed and if strong anti-Stokes lines also exist, then this finding is in accordance with the suggestion that cancer cells contain unattached electrons such that their plasma frequency is close to the frequency of the coherent vibrations discussed above.

- 5962 THE EFFECTS OF MICROWAVE RADIATION, HYPERTHERMIA, AND L-ASCORBIC ACID ON EHRlich ASCITES CARCINOMA CELL METABOLISM. (Eng.) Piontek, G. E. (Radiation Oncology Training Program, Univ. Illinois, Urbana, IL); Cain, C. A.; Milner, J. A. *IEEE Trans Microwave Theory Tech* 26(8): 535-540; 1978. (41 refs)

The effects of 2.45-GHz microwave radiation, hyperthermia, and L-ascorbic acid on glucose and citrate metabolism in Ehrlich ascites tumor cells *in vitro* are studied, and these data were compared to glucose metabolism in rat kidney slices. Microwave-irradiated and nonirradiated water bath cells were maintained at 37.5 C and 42.5 C in the presence or absence of L-ascorbic acid. The metabolic responses of Ehrlich ascites tumor cells and rat kidney slices were not different between irradiated and nonirradiated samples. Ascorbic acid increased the rate of glucose and citrate metabolism, and this effect was found at 37.5 and 42.5 C in both irradiated and nonirradiated cells. No significant differences in glucose or citrate metabolism were found between irradiated and nonirradiated cells at the same temperature and ascorbic acid concentration. Hyperthermic treatment alone for 1 hr did not significantly affect tumor cell metabolism; however, hyperthermia in the presence of ascorbic acid significantly increased tumor cell citrate metabolism but not glucose metabolism. This result held for both irradiated and nonirradiated cells. When glucose metabolism in normal kidney tissue slices from rats was studied, there was no significant changes with or without ascorbic acid. In addition, there were no significant metabolic changes resulting from incubation at 42.5 C versus 37.5 C.

- 5963 A SYSTEM FOR DEVELOPING MICROWAVE-INDUCED HYPERTHERMIA IN SMALL ANIMALS. (Eng.) Baker, R. J. (Radiation Oncology Center, Parkview Memorial Hosp., Fort Wayne, IN 46805); Smith, V.; Phillips, T. L.; Kane, L. J.; Kobe, L. H. *IEEE Trans Microwave Theory Tech* 26(8): 541-545; 1978. (19 refs)

A system for producing microwave-induced hyperthermia in small laboratory animals by irradiating

an entire transverse section of the animal is described. The applicator consists of a conventional WR-650 coax-to-waveguide adapter followed by an electrically compensated transition section (tapered in the height dimension only) to adapt the larger component to the reduced height waveguide test section. The relatively large WR-650 waveguide allows the use of a low frequency to ensure good depth of penetration but of reduced height to limit the region of heating. The frequency of the system is 1,210 MHz; this was chosen based on measurements that indicated maximum energy absorption in the test animal at this frequency. In an initial trial, anesthetized mice were heated to 41.2 C for 25 min or to 44.8 C for 15 min at this frequency using a 1.91-cm high microwave section. Long-term survival was not obtained in this trial. Uniform heating (within 0.25 C) resulted when a test tube containing the mouse was rotated 180 degrees at four times/min during the heating period. Of 17 animals heated to 44.8 C for 5 or 10 min, throughout the entire abdominal region, 7 survived for 7 days postheating. Histologic data obtained after 3 days from animals heated to 44.8 C for 15 min indicated damage of the crypt cells and villi of the jejunum only. The kidney, lung, liver, and spleen were all normal. Based on these preliminary studies, it appears possible to assess cellular and tissue damage in tumor and normal tissue of animals exposed to microwave hyperthermia.

5964 BIOLOGICAL EFFECT OF 27.12-MHZ SHORT-WAVE DIATHERMIC HEATING IN EXPERIMENTAL TUMORS. (Eng.) Overgaard, J. (Inst. Cancer Res. and the Radium Center, Aarhus Municipal Hosp., DK-8000 Aarhus C, Denmark). *IEEE Trans Microwave Theory Tech* 26(8): 523-529; 1978. (24 refs)

Short-wave diathermy (27.12 MHz) in the temperature range of 41-43 C was used to treat 12 isologous transplantable mouse tumors of different origin, histology, and degree of differentiation. Local tumor control was obtained after a minimum threshold heat dose (combination of temperature and treatment time), but curability varied from 9-25% in different tumors. The cures were obtained without evidence of damage to normal tissue, therefore, tumor destruction seemed to be a selective process. Curative results did not improve when the heat dose was increased beyond the threshold dose by a factor of up to four. The initial clinical response was the same in all tumors treated with a curative heat dose. The tumor shrank, became increasingly firm, and gradually disappeared; however, in about 80% of the cases, recurrent growth appeared within 1-2 wk. This recurrence was always found in the periphery of the treated tumors. Histopathologic examination of recurrent tumors demonstrated that in many cases a small marginal spot of viable tumor cells causing the regrowth could be observed. This was especially found as small tumor islands situated in the surrounding fatty or connective tissue. Although a general threshold dose seemed to be required to obtain a curative effect in the tumors, the curative yield following the actual threshold dose was not the same in all tumors, showing var-

iations ranging from a few to about 25%. The degree of peripheral infiltrative growth was the only parameter that correlated with the cure rate: tumors with a narrow corona had a higher number of cures than tumors with more infiltrative growth. It seems that a heterogeneous and insufficient physical destruction by the heat applied by the present diathermy technique is the most likely explanation for tumor regrowth. Therefore, the usefulness of low-frequency diathermy in tumor control is limited by the application technique and by the tissue heterogeneity.

5965 DEVELOPMENT OF A 915-MHZ DIRECT-CONTACT APPLICATOR FOR THERAPEUTIC HEATING OF TISSUES. (Eng.) Guy, A. W. (Dept. Rehabilitation Medicine RJ-30, Univ. Washington Sch. Medicine, Seattle, WA 98195); Lehmann, J. F.; Stonebridge, J. B.; Sorensen, C. C. *IEEE Trans Microwave Theory Tech* 26(8): 550-556; 1978. (12 refs)

A 915-MHz diathermy dielectrically-loaded applicator with a TE₁₀-mode aperture field distribution is described. The applicator consists of a transition from a coaxial connector to a stripline power splitter that supplies power to two independent waveguides by excitation loops. A porous foam dielectric (dielectric constant of 4) is used that allows cooling air to be blown through the applicator and onto the surface of tissue being treated. When the applicator was oriented with the electric field perpendicular to the femur of human volunteers, it was reasonably matched for this position from direct contact with the tissue to a distance of 3 cm from the tissue. When the applicator was turned 90 degrees so that the electric field was parallel to the femur, the applicator was still reasonably matched at distances of 0-2 cm from the tissue surface. The applicator was tested continuously under high power conditions up to 600 W, and it performed satisfactorily with negligible heating of the dielectric material and the metal hardware. Bandwidth evaluations of the applicator indicated that it is matched over the frequency range of 880-940 MHz, which is more than adequate for covering the 915 ± 13-MHz band. Previous results indicate that with 1 W of input power, the applicator can produce a maximum specific absorption rate of 3.25 W/kg in muscle. Therefore, an input power of 50 W is sufficient to produce a specific absorption rate of 150 W/kg in muscle, which is more than adequate for typical clinical use.

5966 VDUs—AN OPERATOR'S VIEW. (Eng.) Timbs, O. (No affiliation given). *Occup Health* 30(8): 363; 1978. (0 refs)

Problems associated with working with visual display units (VDU) are discussed from an operator's viewpoint. Although the operator was prepared to accept the evidence that working with VDUs is 100% medically safe, long periods of VDU operation were nevertheless irritating. The main problem that the operator experienced was flashing messages

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that appeared across the VDU screen. Since the "refresh rate" of the modern VDU screen is at least 50 Hz, in contrast to the 25 Hz for domestic television sets, flickering should not be very much of a problem. However, the software that this particular operator deals with is very delicate, and while working on a program, the operator could easily make an error with the result that messages of warning flash across the screen until the mistake is rectified. These incessant flashes, apparently, are most exhausting. The operator feels that only in exceptional circumstances should an operator work on a VDU for more than 2 hr without a break. This view is supported by industrial committee guidelines for VDU operators, which recommend at least a 30-min break from the screen after every 2-hr work period at the VDU.

5967 PULSED MICROWAVE-DIATHERMY. (Eng.) Willebrand, A. (Jousterweg 4, HASKERHORNE [Fr], 9350, Netherlands). *Biomed Tech (Berlin)* 23(7/8): 158-155; 1978. (16 refs)

Continuing studies of heating pattern, temperature elevation, and pearl chain formation were conducted with a pulsed microwave applicator (Diatron-1500) operating at a frequency of 2,450 MHz. The applicator delivers both continuous microwave radiation and pulsed microwave radiation with a pulse duration of 60 μ sec. The energy dosage is regulated by varying the number of pulses over eight dial settings from 100-900 pulses/sec; the first four settings are denoted as diatronic athermic therapy and the latter four as diatronic thermic therapy. Heating pattern studies using the egg white coagulation method revealed that none of the pulse rate settings resulted in any visible sign of coagulation; whereas, the first sign of coagulation occurred within 10 min after switching the applicator on the continuous microwave setting. In the gluteal muscle of rabbits, there was no observable temperature rise after exposure to pulsed microwaves (any pulse rate setting) for 20 min. In contrast, a definite rise in temperature was recorded from the beginning of radiation when continuous microwaves were used. Similar negative results were obtained in dog muscle for the first four pulse rate settings (diatronic athermic therapy); however, a slight and slow temperature rise (about 1 C) occurred during 20 min of irradiation for the four diatronic thermic therapy settings. Continuous microwave irradiation resulted in a strong temperature rise of nearly 3 C within 20 min of exposure for dog muscle. Pearl chain formation with diluted milk and with blood was easily demonstrated with pulsed microwave radiation at the lowest diatronic athermic settings.

5968 HEAT POTENTIAL DISTRIBUTION IN AN INHOMOGENEOUS SPHERICAL MODEL OF A CRANIAL STRUCTURE EXPOSED TO MICROWAVES DUE TO LOOP OR DIPOLE ANTENNAS. (Eng.) Hizal, A. (Electrical Engineering Dept., Middle East Technical Univ., Ankara, Turkey); Baykal, Y. K. *IEEE Trans Microwave Theory Tech* 26(8): 607-612; 1978. (8 refs)

Heat potential distribution is calculated for a multilayered inhomogeneous spherical model of a cranial structure situated symmetrically in the near zone of either a small loop antenna or an electrical dipole antenna radiating at a frequency of 3 GHz. The idealized model chosen was a six-layered spherical model with a maximum radius of 3.3 cm, which might correspond to a monkey's or an infant's head. At 3 GHz frequency, the peak internal heat potential makes a maximum for the plane-wave excitation. The permittivity and the conductivity of the layers were taken at this specific frequency with sharp sinusoidal transitions between the layers. For the dipole excitation, a rather uniform heat potential distribution was found to occur, with no considerable hot spots. For the loop excitation, a significant hot spot occurred near the center of the structure. When compared with the plane-wave excitation, it was seen that the exact center of the head could best be heated by the plane-wave incidence. Also, for all excitations, a concentration of heat at this frequency and cranial size could be observed at the skin because of the high conductivity of this outermost layer.

5969 SOME BIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS BELOW 300 MHz (PREGNANCY, LITTER SIZE AND GONADOTROPIC ACTIVITY OF THE ANTERIOR LOBE OF THE PITUITARY GLAND). (Pol.) Mikołajczyk, H. (Instytut Medycyny Pracy, ul. Teresy 8, 90-950 Lodz, Poland). *Med Pr* 29(2): 111-120; 1978. (9 refs)

The fecundity and litter size were investigated in three successive generations of 31 control and 21 experimental female rats irradiated before and/or during pregnancy in electromagnetic fields of 30, 70, or 210 MHz at 200 V/m intensity for 2 hr/day. While all experimental rats became pregnant, the litter size of the rats irradiated at 70 MHz was 70% that of the controls. The male-to-female ratios in the litters were 29:29 after irradiation at 70 MHz, 63:55 after irradiation at 30 MHz, and 22:26 after irradiation at 210 MHz. The follicle-stimulating hormone (FSH), luteinizing hormone (LH), and growth hormone (GH) levels of the anterior lobe of the pituitary gland were determined in 35 male and 21 female sexually immature rats irradiated once (100 MHz, 2-0 V/m, 2 hr) or repeatedly (227 KHz or 210 MHz, 200 V/m, 40 x 2 hr). Thirty-five males and 21 females served as intact controls. Single-time irradiation of males caused a significant increase in the LH and GH levels; irradiation with 210 MHz caused significant or nearly significant decreases in the FSH, LH, and GH levels. Irradiation with 227 KHz caused significant decrease in the LH and GH levels.

5970 INFLUENCE OF A CONSTANT MAGNETIC FIELD ON NERVOUS TISSUES: I. NERVE CONDUCTION VELOCITY STUDIES. (Eng.) Schwartz, J.-L. (Laboratoire de Physiologie Animale, Université de Poitiers, Poitiers, France). *IEEE Trans Biomed Eng* 25(5): 467-473; 1978. (25 refs)

The effects of a constant magnetic field (1.2 tesla) on the propagation velocity of nerve impulses along the circumesophageal nerve of the lobster (*Homarus Americanus*) were investigated. Nerve chambers with either straight or V-shaped electrodes were constructed from acrylic plastic with one section at 90 degrees to the other in such a way that the nerve would be held in an L-shaped groove, with the long side of it perpendicular to the magnetic field and the short side parallel to the field. The nerve was first stimulated for a 5-10-min period to check for healthy condition and stability. The magnet was then energized to establish the magnetic field in the air gap where the experimental chamber was located. The exposure period lasted usually 20-30 min after which the magnetic field was brought back to zero. The electrical response of the nerve was then monitored during another period of 20 min. During the exposure and postexposure periods, the stimulation was kept supramaximal and at a frequency of 0.1 Hz. Each nerve thus served as its own control. The results indicated that the magnetic field had no significant influence on the propagation velocity of the impulse along the circumesophageal nerve of the lobster in either parallel or perpendicular configuration with respect to the magnetic field vector direction.

- 5971 PRELIMINARY OBSERVATIONS WITH AN ELECTROMAGNETIC METHOD FOR THE NONINVASIVE ANALYSIS OF CELL SUSPENSION PHYSIOLOGY AND INDUCED PATHOPHYSIOLOGY. (Eng.) Larsen, L. E. (Walter Reed Army Inst. Res., Dept. Microwave Res., Washington, DC); Jacobi, J. H.; Krey, A. K. *IEEE Trans Microwave Theory Tech* 26(8): 581-595; 1978. (40 refs)

A method for the high-speed noninvasive electromagnetic analysis of cell suspension physiology and induced pathophysiology is presented. The method is especially suitable for pathophysiologic applications where a high rate of data acquisition is necessary. This requirement is met by the technique of automatic network analysis and off-line processing to derive complex permittivity from the error-corrected complex reflection coefficient. The present system offers some freedom from the interfacial effects that plague all permittivity measurements in electrolytes insofar as platinum/platinum black is used only in a calibration step. Experimental results demonstrate that changes in high frequency band permittivity dispersion may be related to physiologic and drug-induced pathophysiologic states of the cell membrane. The effect of species, suspending medium, and temperature are systematically analyzed in erythrocyte suspensions to aid a comparison between published studies of red blood cell preparations. Absolute measurements, subject to limitations involving the frequency range and dielectric constant, appear to be within the range of variation in the published literature once all contributing factors are considered. The method appears to have useful sensitivity to small movements of water and electrolytes. A system for the interpretation of cell suspension dispersion is presented along with experimental evidence to support

the interpretive scheme. The method offers the potential for noninvasive measurement whereby the contribution of intracellular and extracellular spaces may be separately analyzed. It is asserted that the physiologic foundation for the observed dispersion is the cell membrane and that its activity may be inferred without the need for membrane disruption.

- 5972 THE ELECTROMECHANICAL EFFECT IN BONE. (Eng.) Johnson, M. W. (Ph.D. dissertation, Univ. Illinois at Urbana-Champaign, 1977); 135 pp. [available through National Technical Information Service, Springfield VA 22161, Document No. C00-1198-1183]. (58 refs)

The physics of piezoelectricity in bone is examined, with particular reference to the applicability of the stress gradient theory to both dry and wet bone. Experiments with dry bone from bovine tibia led to the conclusion that the otherwise anomalous electromechanical effect in bent dry bone is due to spatial variations in the piezoelectric moduli. This result unified the electromechanical phenomena for dry bone under one effect, the piezoelectric effect. A model for the piezoelectric behavior of an osteon in which an osteon resembles a radially-poled cylinder is also presented. There is some evidence that this model is applicable to an osteon, but further experimental work on the microscopic piezoelectric behavior of bone is needed to test this model. The possibility that trapped charge may contribute to the electromechanical effect in bone through the electrostriction effect was considered, and it was concluded that although this theory may be applicable to some polymers, it is not applicable to bone. It is suggested that the electromechanical effect in poled polyvinylidene fluoride in cantilever bending may be due to spatial variation in the piezoelectric moduli. Measurements on wet bone showed that the electromechanical effect in bent wet bone exhibits the same z -dependence and symmetry properties that are characteristic of dry bone and that the magnitude of the effect in wet bone is of the order expected if the signals had the same origin. It is concluded that the effect in bent wet bone is due to variations in the piezoelectric moduli. However, the sign of the signal observed in wet bone is always positive, even for samples that have a negative signal when dry. It is tentatively concluded that there is more than one effect contributing to the signal in wet bone and that part of that signal is due to a variation in the piezoelectric moduli.

- 5973 SURVEYS OF ELECTROMAGNETIC FIELD INTENSITIES NEAR REPRESENTATIVE HIGHER-POWER FAA TRANSMITTING ANTENNAS. (Eng.) Larsen, E. B.; Shafer, J. F. (Electromagnetics Div., Inst. for Basic Standards, Natl. Bureau Standards, Boulder, CO 80302). 115 pp.; 1977. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD A051717]. (17 refs)

Data from an NBS survey of electromagnetic field intensities near the antennas of typical higher power Federal Aviation Administration transmitting systems are presented. These systems include ground surveillance radars, airborne weather radars, instrument landing systems, and various navigation and communication radiators, or any system likely to produce an equivalent free space power density exceeding 0.1 mW/cm^2 or an electric field magnitude above 20 V/m . Commercial monitors with thermocouple sensors were used to measure electric fields between 0.5 and 24 GHz and magnetic fields between 10 and 300 MHz . Probes designed at NBS with diode detectors were used for electric fields between 100 kHz and 10 GHz . The intensity in the direct beam of air route surveillance radars was greater than 10 mW/cm^2 at distances within about 14 m from the antennas. The intensity of airport surveillance radars was above 10 mW/cm^2 at distances within 15 m , except for a newer airport surveillance radar model (ASR-8). For all aircraft radars checked, no intensity exceeding 10 mW/cm^2 was found at a distance beyond 6 m . Taking the time-averaging effect for antenna scanning into consideration, these field values would be greatly reduced. Also, the near-zone beams of such antennas are not normally accessible to personnel. In accessible areas the measured fields were generally less than 1 mW/cm^2 .

- 5974 A MAGNETIC COMPASS RESPONSE OF AN ORGANISM. (Eng.) Brown, F. A.; Bennett, M. F.; Webb, H. M. (Dept. Biological Sciences, Northwestern Univ., Evanston, IL). 10 pp.; 1960. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD 247 747]. (3 refs)

Snails (*Nassarius obsoleta*) were placed in magnetic fields at right angles to one another to determine whether the animals possess a capacity to differentially respond to such fields. The experiments comprised permitting snails to emerge from a magnetic-south-directed, straight, narrow corridor into a constant, symmetrical field provided with a grid such that the mean amount of right or left turning during the initial 3 cm of free movement could be assayed. Each experimental series consisted of two samples of 10 passages in the earth's field, two samples of 10 passages in an experimentally increased field oriented as the earth's field, and two samples of 10 passages in an increased field rotated 90 degrees clockwise from the natural field. A total of 564 series of 60 snail runs was obtained between the hours of 5 AM and 9 PM . The results indicated that the snail is able to differentiate between two weak magnetic fields, one oriented at right angles to the other. The relative influences of experimental north-south and east-west oriented magnetic fields in producing dispersion of snail pathways, or effecting a magnetokinesis, displayed both solar- and lunar-day rhythms. The relative influences of experimental north-south and east-west fields in effecting a predominantly counter-clockwise snail-turning exhibited solar daily,

lunar daily, and semi-monthly rhythms. The solar and lunar clock-regulated discriminatory responses for magnetic fields indicate that the snail is significantly oriented as if by internal magnetic compass needles, which in turn are hands of horizontal solar- and lunar-day clocks.

- 5975 QUANTITATION OF MICROWAVE RADIATION EFFECTS ON THE HEAD AND EYES OF RABBITS, PRIMATES AND MAN. (Eng.) Kramer, P. O. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine RJ-30, BB 919 Health Sciences, Univ. Washington, Seattle, WA 98195). 11 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD A054421]. (8 refs)

The right five eyes of five adult albino rabbits were exposed for 5-min periods either every other day or every third day to a subthreshold apparent power density level of 300 mW/cm^2 from a $2,450\text{-MHz}$ microwave C director to determine the effect of such exposures on cataract formation. The left eyes of these same rabbits served as controls. Cataract formation was observed in three out of three rabbits exposed to microwave radiation every other day; whereas, no cataracts were observed in two rabbits exposed every third day to microwaves. Therefore, it appears that 2 days are required between exposures to allow the lens to recover. Post-irradiation retrolental temperatures of between 42 and 46°C were recorded in all cases. When circulating hot water was used to elevate the retrolental temperature of rabbits to 43 or 45°C , lens changes similar to those following acute microwave irradiation were observed. These findings combined with the lack of detectable lens changes following chronic low level irradiation suggest that the presence of a specific nonthermal microwave factor is unlikely in cataractogenesis.

- 5976 HAZARDS DUE TO TOTAL BODY IRRADIATION BY RADAR. (Eng.) Schwan, H. P.; Li, K. (Moore Sch. Elec. Engrg., Univ. Pennsylvania, Philadelphia, PA). 10 pp.; 1956. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD 122467]. (18 refs)

Hazards due to total body irradiation by radar are theoretically analyzed in terms of the percentage of airborne electromagnetic energy absorbed by the human body and the distribution of heat sources in the various tissues of the body. It is assumed that plane electromagnetic radiation is propagating perpendicular to the surface of the body. This case will be approximated roughly by the trunk of a person facing the source of radiation. Taking 0.01 W/cm^2 for long time exposure and 0.01 W/hr/cm^2 for short exposures as tolerance figures, both not to be exceeded in the case of total body irradiation, the following conclusions seem justified. Frequencies substantially below $1,000 \text{ MHz}$ (500 MHz and lower) are associated with true deep heating. The coefficient of absorption is about $30\text{-}40\%$. This means that incident energy

flux figures of less than 0.03 W/cm^2 can be tolerated. Frequencies ranging from 1,000-3,000 MHz may be absorbed completely. Skin, subcutaneous fat, and deep tissues participate in this absorption, and conversion into heat occurs in a complex manner. Here the percentage of airborne energy that is absorbed by the body may vary between 20 and 100%, depending on the thickness of the skin and subcutaneous fat. Hence, 0.01 W/cm^2 is considered as a recommendable tolerance statement. Frequencies in excess of 3,000 MHz are absorbed in the surface of the body, and heat dissipation to the outside is excellent. The coefficient of airborne energy that is absorbed is 40-50%. Hence, more than 0.02 W/cm^2 is tolerated by the body.

5977 THE EFFECT OF LOW FREQUENCY RADIO WAVES ON BIOLOGICAL MATERIALS. (Eng.) Ginsburg, N.; Cholet, P. (No affiliation given). 20 pp.; 1954. [available through Armed Services Technical Information Agency, Dayton, OH, Document No. AD 24365]. (2 refs)

The effect of low frequency radiowaves on the viability of two varieties of *Zea mays* seeds (Golden Bantam and Ear-Bred varieties) is investigated. Lethal effects were produced when the seeds were exposed to a frequency of 20 MHz at 800 V root mean square for periods of 4.5 hr. The heating effect under these conditions was pronounced. Measurements of dissipation factor versus frequency as a function of temperature were extended to the 10 MHz frequency range, and the two varieties of corn compared with sunflower seeds. Measurements were also made to compare dehydrated seeds with frozen seeds. Freezing and dehydration had similar effects on the dissipation factor. Graphs showing the variation of equivalent parallel resistance with frequency were constructed from quantities measured in the present experiments and in past experiments. There was a close similarity between these curves for various conditions. It is suggested that the lethal effects observed after 20-MHz irradiation are probably due only to heating. At the low frequency end of the measurements, the greatest probability is that the observed effects are nearly all due to ionic conduction within the seeds. It is assumed that the conduction mechanism is very sensitive to small amounts of water as indicated by large changes in the dissipation factor produced by freezing and the nearly identical changes produced by dehydration. No definite statement may be made on the changes in conduction mechanism produced by heating. The large increases in dissipation factor and the increase in the dielectric constant at low frequency are not due to molecular reorientation but to ionic polarization effects.

5978 AN ANALYSIS OF RADIOFREQUENCY AND MICROWAVE ABSORPTION DATA WITH CONSIDERATION OF THERMAL SAFETY STANDARDS. (Eng.) Tell, R. A. (Environmental Protection Agency, Office Radiation Programs, Electromagnetic Radiation Analysis Branch,

P.O. Box 15027, Las Vegas, NV 89114). 56 pp.; 1978. [available through National Technical Information Service, Springfield, VA. Document No. EPA Technical Note, ORP/EAD 78-2]. (103 refs)

An analysis of the existing radio frequency (RF) and microwave (MW) absorption data for man in relation to electromagnetic power deposition in tissues of the body leading to various levels of thermal loading is presented. The results illustrate the strong frequency-dependent nature of electromagnetic energy absorption in man and the existence of resonance frequencies for the body as a whole and the anatomic substructures. The analysis reveals a particularly important resonance frequency range, 10 MHz to 1,000 MHz, in which RF and MW absorption may lead to whole body thermal loads several times the whole body basal metabolic rate for exposures equal to the present safety standard in use in the United States. For the human adult, at a resonance frequency of about 70 MHz, a free space exposure field of 140 nJ/m^3 electromagnetic field energy density (a far-field equivalent of 4.2 mW/cm^2 power density) will induce a doubling of the heat load due to the basal metabolic rate. This would probably be detectable as a rise in body temperature by most individuals at rest. While the whole body heat loading is only doubled, the nonuniform nature of the absorption process could potentially lead to localized absorption rates as high as 30 W/kg . Such a high local absorption rate is probably not advisable for the general population. The results reveal serious reservations for applying the currently used American National Standards Institute standard to the population as a whole in that localized power deposition could, under proper conditions of exposure, apparently lead to substantial thermal burdens in various parts of the body. The adoption of more conservative limits would not appear in general to impose undue hardships on existing facilities inasmuch as environmentally encountered RF and MW intensities are rarely above 4 nJ/m^3 .

5979 EFFECT OF COBALT-60 RADIATION, MICROWAVE HYPERTHERMIA AND PARA-FLUOROPHENYLALANINE ON HAMSTER MELANOMA. (Eng.) Traub, R. J. (Ph.D. dissertation, Purdue Univ., 1977); 131 pp. (available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 78-13,131). (31 refs)

The effects of cobalt-60 radiation (500 rad per treatment) alone and in combination with 2.45-GHz microwave hyperthermia (43 C for 15 min) and p-fluorophenylalanine (100 or 200 mg/kg per treatment) on a slightly pigmented and a nonpigmented melanoma syngenic to golden Syrian hamsters was investigated to determine if hyperthermia or the drug could enhance radiosensitivity or if the drug could enhance the thermosensitivity of these tumors. The animals were exposed to radiation and hyperthermia every other day for five treatments. Hyperthermia preceded cobalt-60 radiation by approximately 5-10 min. p-Fluorophenylalanine was administered intraperitoneally for 10 daily treatments. Cobalt-60 radiation significantly

decreased tumor growth in both tumor types studied (at day 15, 36% of control for low passage and 16% of control for high passage derived tumors), and this resulted in an increased survival time after the initial treatment. Microwave hyperthermia had a significant effect on reducing tumor growth on day 5, 10, and 15. However, the influence on tumor growth did not result in a significant effect on the survival of tumor-bearing animals. p-Fluorophenylalanine had a significant influence on tumor growth for all days studied. The decreased tumor growth did not result in an increased survival time after the initial treatment. Although there was a significant decrease in tumor growth for high passage derived tumors compared to low passage derived tumors as a result of cobalt-60 radiation, there were no consistent differences between the two tumor types with respect to their response to microwave hyperthermia or p-fluorophenylalanine. The combination of cobalt-60 radiation with microwave hyperthermia and/or p-fluorophenylalanine showed no significant synergism. The combined treatment effects could be predicted by assuming independent additivity of the main treatment effects.

- 5980 BIOMAGNETISM: A REVIEW. (Eng.) St. Lorant, S. J. (Stanford Linear Accelerator Center, Stanford Univ., Stanford, CA 94305). 9 pp.; 1977. [available through National Technical Information Service, Springfield, VA 22161 Document No. CON-770842-18]. (89 refs)

A literature review of the biologic effects of static and slowly varying magnetic fields is presented. In general, magnetic effects appear to be fully reversible once the organism is permitted to return to its original environment. No experimental evidence exists that would indicate a cumulative effect caused by repeated exposures without adequate recovery times between exposures. A survey of hundreds of experiments performed in the last 20 yr in which mice, plants, insects, lower organisms, primates, and humans were subjected to magnetic fields of varying degrees shows that magnetic fields provoke biologic responses, which may be placed into four classes according to the mechanism or reaction that produces them. The first class consists of effects that seem to originate in some kind of sensory apparatus through which the organism can detect magnetic fields of the order of the geomagnetic field. The second class encompasses physiologic stress effects, which result from the many physical processes that occur in an organism subjected to a magnetic field. The third class encompasses all possible mutagenic effects of magnetic fields. The evidence for these is rather mixed, and the question of possible genetic effects is still open. The fourth class comprises magnetic effects that appear only in the presence of other physical parameters, such as, ionizing radiation, temperature, and oxygen tension. Even though knowledge on the biologic effects of magnetic fields seems to be inconclusive, a set of safety guidelines was recommended by the Stanford Linear Accelerator

Center in 1970. For extended periods (hours), maximum exposures of 0.02 tesla for the whole body or head and 0.2 tesla for the arms and hands are recommended. For short exposure periods (minutes), a maximum exposure of 0.2 tesla for the whole body or head and 2 tesla for the arms and hands are recommended. These recommendations, which have found their way into the safety codes of many laboratories in the West, reflect the results of a survey of biomagnetic literature up to 1970. As no significant developments in the field have taken place since that time, the standards have remained unchanged.

- 5981 PAVLOVIAN CONDITIONING OF MICROWAVE-INDUCED HYPERTHERMIA IN THE RAT. (Eng.) Bermant, R. I. (Ph.D. dissertation, Univ. Kansas, 1977); 159 pp. (available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 78-12,023). (340 refs)

Experiments on Pavlovian conditioning of microwave-induced hyperthermia were performed to determine if a rise in core temperature is amenable to classical conditioning in a small mammal. A relatively pure hyperthermal response, presumably uncontaminated by a major emotional component, was produced by using microwave radiation (2,450 MHz) as an unconditional stimulus. A group of rats exposed to a noxious electric shock was also used so that comparisons could be made between the hyperthermia secondary to emotional arousal induced by an electric shock and the primary (non-emotional) hyperthermia induced by exposure to microwave radiation. Control animals were presented only with the conditional stimulus (30 sec of tone), thus providing a baseline against which the hyperthermal reactions of the experimental animals could be evaluated. An analysis of the data obtained from these experiments revealed that animals exposed to either microwave radiation or to the electrical shock developed generalized hyperthermal reactions that were triggered by the conditioning milieu. In contrast, control animals placed in the same environment, but in the absence of an unconditional stimulus, exhibited statistically reliable declines of colonic temperature. The conditional hyperthermia of the experimental animals proved highly resistant to extinction and persisted after 100 unreinforced presentations of the conditional stimulus. Taken as a whole, the data indicate that hyperthermia induced either by electrical shock or by exposure to microwave radiation is highly general and is highly resistant to extinction.

- 5982 ELF ELECTRIC AND MAGNETIC FIELD SIMULATION FOR A LABORATORY BIOLOGICAL EXPERIMENT. (Eng.) Gauger, J. R. (IIT Res. Inst., 10 West 35th St., Chicago, IL 60616). 59 pp.; 1978. [available through National Technical Information Service, Springfield, VA, Technical Report E6357-10]. (0 refs)

An extremely low frequency (ELF) electromagnetic field simulator, which operates at a center frequency of 76 Hz, is described. The simulator was designed and built in support of biologic tissue culture experiments performed at the Naval Medical Research Institute in Bethesda, Maryland. The simulator generates uniform electric and magnetic fields having the same characteristics as those produced by the Navy's proposed ELF communications system.

- 5983 CHARACTERIZATION OF A SMALL CHAMBER USED FOR EXPOSURE TO MICROWAVE RADIATION OF SMALL ANIMALS. (Eng.) Yeandle, S. S.; Bassen, H.; Thomas, J. R. (Naval Medical Res. Inst., Bethesda, MD 20014); 13 pp.; 1978. [available through National Technical Information Service, Springfield, VA, Report No. NMRI 78-17]. (5 refs)

A chamber for exposing rats to 2,450 MHz radiation in studies of microwave-induced behavioral effects is described. The irradiation chamber consists of a wooden frame upon which rectangular blocks of microwave absorber are placed. Reflection of 2,450 MHz radiation from the absorber is rated at 20 dB. For exposure to radiation the rat is placed in a sleeve of fine plastic netting, the ends of which are tied with string so that the rat can not move. The harness is hung from a wooden frame, and the frame is placed in the chamber so that the rat's head is lying along the boresight (axis of propagation) of a horn antenna placed at the mouth of the chamber. The horn is a standard gain type designed to be operated in the range of 2.6-3.95 GHz and is thus slightly mismatched to the 2.45 GHz radiation used in the behavior studies. The horn is fed by a pulsed microwave generator. Pulses of microwaves of variable repetition rate and pulse duration can be produced by switching on and off the supply voltage to a resonant cavity oscillator. The variation in the field in the absence of the rat over the space occupied by the rat's head is not very great (about 10%) even though the field over the entire rat's body varies greatly (as much as 50%). In the absence of the rat, standing waves, although noticeable, are not large. When the rat is present, because it is a conducting body of complicated shape, the field is distorted and large standing waves are set up in front of the rat.

- 5984 COMPILATION AND ASSESSMENT OF MICROWAVE BIOEFFECTS: A SELECTIVE REVIEW OF THE LITERATURE ON BIOLOGICAL EFFECTS OF MICROWAVES IN RELATION TO THE SATELLITE POWER SYSTEM. (Eng.) Justesen, D. R.; Ragan, H. A.; Rogers, L. E.; Guy, A. W.; Hjerlesen, D. L.; Hinds, W. T. (Battelle Memorial Inst., Pacific Northwest Lab., Richland, WA 99352). 86 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. PNL-2634/UC-41]. (138 refs)

A review of the literature on the biologic effects of microwaves in relation to the proposed microwave

satellite power system is presented. Experimental and epidemiological findings indicate that thresholds of relatively short-term radiation for morbid biologic effects (e.g., cataracts, heart disease, hematologic effects, immunologic disturbances, and genetic and developmental defects) are well above the maximal power density (1 mW/cm^2) that is tentatively projected at and beyond the area of exclusion of the receiving antenna for the 2,450-MHz continuous wave microwave satellite power system. However, no experimental study has ever been performed that even remotely approaches the 30 yr or more that the satellite power system would be operative. In addition, no data are available with respect to consequences for airborne species that may fly over the receiving antenna or for terrestrial or airborne species that may ascend or descend to the surface of the antenna, thereby incurring radiation at power densities that could exceed 20 mW/cm^2 . Only intensive experimental study can reveal whether the satellite power system concept can be safely implemented.

- 5985 ELF ELECTRIC FIELD ANALYSIS FOR A LABORATORY BIOLOGICAL EXPERIMENT. (Eng.) Shiau, Y. (IIT Res. Inst., 10 West 35th St., Chicago, IL 60616). 71 pp.; 1978. [available through National Technical Information Service, Springfield, VA, Technical Rpt. E6357-9]. (8 refs)

An analysis of the electric field levels induced in individual tissue culture samples when exposed to uniform electric and magnetic fields in a laboratory simulator operating at a frequency of 76 Hz is presented in connection with the Navy's proposed Seafarer extremely low frequency (ELF) communications system. The following observations and conclusions are drawn from the study. The ELF magnetic field will penetrate the tissue cultures without change. As anticipated, the induced electric field internal to the biologic tissue in the tissue culture tray decreases as the permittivities of the tissue and its surrounding medium increases. The ELF electric field internal to the tissue sample will be much less than the applied field. For a single layer of trays, the reduction factor is about 6×10^7 . The electric field coupling to the tissue also depends on the separation between the tissue culture tray and the upper and lower plates of the simulator. Maximum internal field strength is achieved when the parallel plates are placed right on and beneath the culture tray. Like the ELF electric field coupling to a single isolated biologic object, the coupling is stronger for objects having a more elongated geometric shape. The coupling is strong when the object exhibits a geometric shape somewhat like a long and thin circular cylinder. On the other hand, the coupling is small for a geometric shape. From the limited numeric results obtained in this study, it appears that the array spacing and the object size also affect the electric field coupling. However, the effect, which primarily arises from the variation in the effective permittivity of the tissue culture tray for different array spacing and object

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size, is not significant at extremely low frequencies. Although sophisticated field theory was required to analyze the complex geometry used in this experiment, an adequate estimate of the field coupling can be obtained using a simple circuit model. This model also aids in the understanding of the coupling mechanism.

- 5986 REVIEW OF OCCUPATIONAL SAFETY AND HEALTH ASPECTS OF ELECTROMAGNETIC PULSE EXPOSURE. (Eng.) Bruner, A. (Lovelace Biomedical and Environmental Res. Inst., P.O. Box 5890, Albuquerque, NM 87115). 24 pp; 1977. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD A053394]. (17 refs)

Observations on the occupational safety and health aspects of exposure to electromagnetic pulse (EMP) simulators are reported. These simulators have been in operation in the United States since the early 1960's. Their mission involves the study of electromagnetic fields designed to simulate the intense electromagnetic transient that accompanies a nuclear explosion, which may involve field densities on the order of 10^5 V/m with nanosecond rise and fall times. Experience with EMP worker exposures has accumulated now for more than 20 pulser projects, some of which have been in operation for over 10 yr. To date, no adverse health effects of such exposure have been determined from either repeated physical examinations of personal observations of nearly 600 individuals exposed to EMP. Further, no reports by exposed employees of motivational-emotional changes (e.g., asthenic syndrome) have been ascribed to the EMP exposure environment per se, unlike the psychic complaints of microwave-exposed subjects often mentioned in the Soviet literature. Therefore, sufficient no-effect findings from both human and animal experiences seem to exist to allay fears of an EMP worker hazard, at least for within a 10-yr observational time frame.

- 5987 INTERACTION BETWEEN MICROWAVE AND NEURO-ACTIVE COMPOUNDS. (Eng.) Galloway, W. D.; Waxler, M. (Div. Biological Effects, Bureau Radiological Health, Rockville, MD). 8 pp.; 1977. [available through National Technical Information Service, Springfield, VA 22161, Document No. PB-272 906]. (19 refs)

Rhesus monkeys were exposed to microwaves and/or the serotonin depleter fenfluramine to determine if there is a neurotransmitter-linked mechanism of microwave action. The subjects had been exposed to various drug and microwave radiation regimes while performing a match-to-sample task prior to the onset of the described experiment. The experimental apparatus contained three acrylic plastic stimulus panels, which could be lighted either red or green. Below each stimulus panel was a response lever. For each trial, the center panel was lighted red or green, and a single response on the center lever turned off the center panel and simultaneously lighted the side panels, one red

and one green. Correct matches on the side levers were reinforced on the average of once a minute. Each subject was exposed to continuous wave, 2,450-MHz microwave radiation at dose rates of 1, 3, 5, 10, and 15 W. Each subject was also injected intramuscularly with various doses of fenfluramine. For each subject, the highest dose of fenfluramine that did not produce a change from non-drug baseline behavior was administered in combination with an integral microwave dose rate of 15 W. For each session, eight behavioral measures were calculated: percent correct red and green matches, percent responses on the red choice key, percent responses on the right-side key, and response rates of correct and incorrect red and green key responses. A dose of fenfluramine was found for each subject that resulted in a decrease in response accuracy and in decreased response rates. The minimum effective dose ranged from 0.2-4.0 mg/kg. Integral dose rates of 1-15 W of microwave radiation produced no change in the behavior of any subject. The combination of fenfluramine and an integral dose rate of 15 W, however, produced a severe disruption in the behavior of three of four subjects. Despite the fact that no microwave threshold dose was found, the combination of microwaves and fenfluramine resulted in a substantial behavioral deficit. These findings suggest that microwaves interact with monoaminergic processes in the brain.

- 5988 EFFORTS BY THE ENVIRONMENTAL PROTECTION AGENCY TO PROTECT THE PUBLIC FROM ENVIRONMENTAL NONIONIZING RADIATION EXPOSURES. (Eng.) United States General Accounting Office (Washington, DC). 15 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. PB-279 483]. (1 ref)

Efforts by the EPA to protect the public from nonionizing radiation exposures are reviewed. Currently, there is no official public health standard for exposure to environmental nonionizing radiation sources. According to the EPA, research programs to detect and evaluate biologic effects of nonionizing radiation have not yet generated a sufficient data base on which quantitatively and scientifically sound radiation protection standards can be established for microwaves and other nonionizing frequencies. The EPA plans to decide on the need for protection standards in March 1978, developing Federal guidance by April 1979, if determined necessary. The EPA is currently obtaining data on environmental levels of radio frequency and microwave radiation in urban areas. As of February 1978, EPA had collected measurements in 11 metropolitan areas and will continue similar studies in Denver, Los Angeles, San Francisco, and Seattle during the next 18 mo. The highest levels measured were about $150 \mu\text{W}/\text{cm}^2$. According to EPA officials, the overall median exposure levels measured in urban areas were quite low (less than $1 \mu\text{W}/\text{cm}^2$). About 98-99% of the population would appear to be exposed to levels meeting even the very strict Soviet standard. However, 1 or 2% of the general population may be exposed to

higher levels. For example, EPA measurements approached $2,000 \mu\text{W}/\text{cm}^2$ at the base of a frequency-modulated (FM) radio station antenna on Mount Wilson, California. Measurements in excess of $180,000 \mu\text{W}/\text{cm}^2$ were found on the FM tower itself, thus creating concern for workers who need to climb such towers. In addition to its measurement program, EPA research facilities at Research Triangle Park are developing health effects data to investigate the possible low-level effects findings of the Soviet Union. Preliminary results indicate that such exposures may affect the immune system, create anomalies in mouse litters, and produce a trend toward lowered behavioral performance.

- 5989 DEWAR CALORIMETRY TECHNIQUE FOR DETERMINING SPECIFIC ABSORBED POWER OF RODENTS IN RADIOFREQUENCY FIELDS. (Eng.) Hurt, W. D. (USAF Sch. Aerospace Medicine, Aerospace Medical Div., Brooks Air Force Base, TX 78235). 15 pp.; 1977. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD A054155]. (2 refs)

A Dewar calorimetric technique for determining specific absorbed power in rodents exposed to radio frequency (RF) fields is described. The main component of the Dewar calorimeter is a vacuum flask containing a measured amount of water. A simple mathematic relationship is used to calculate the thermal dose from the RF exposure using the initial and final average temperature of the irradiated sample. The average energy absorbed by the sample is computed from the average temperature of the sample immediately before and after the exposure and from the composite specific heat and the mass of the sample. The average rate of energy absorption can be calculated from the average energy absorbed by the sample by dividing the latter value by the exposure duration as long as the temperature change is linearly proportional to the exposure time. Up to three specific absorbed power determinations were made for each of 18 positions used in a study of mice exposed to 2.6 GHz radiation. The results of free field measurements indicated that the mice absorbed 1.15 W/kg per $1 \text{ mW}/\text{cm}^2$. This factor, when applied to the specific absorbed power data, allowed a comparison of free field measurements with effective power density values. The average of seven inner readings for the free field was only 5% higher than the average of 11 periphery readings. However, for the specific absorbed power measurements, the seven inner readings were 12% higher than those on the periphery, probably as a result of the increase in field resulting from more predominant scatter toward the center than on the edges. These measurements demonstrate the usefulness of the Dewar calorimetry technique in determining absorbed power from microwave fields. The basic system provides a relatively inexpensive method for determining absorbed power in rodents.

- 5990 THE BIOLOGICAL ACTIVITY OF THE DISTURBED GEOMAGNETIC FIELD. (Eng.) Muzalevs-kaya, N. I. In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.). Ltd.): pp. 128-137; 1977. (17 refs)

A theoretic analysis of the biologic activity of disturbed geomagnetic fields is presented. It is shown that the energy density and the power flux density of the geomagnetic field (GMF) at the time of a disturbance generally exceeds the sensitivity threshold of the human organism, expressed in the corresponding units. On the basis of a comparison of the parameters of the threshold sensitivity and the disturbed GMF, and proceeding from the general principles of reception, it is shown in principle that an interaction between the human organism and the magnetic field of the earth is possible. The position of the GMF was determined on a common scale of the energy parameters of the ecologic factors, and the character of the reaction and the interaction of the GMF with the organism were investigated at the structural level from the standpoint of theoretic biology. It was demonstrated that the first half of the phase of excitation of biologic structures corresponds, on the indicated energy scale, to the position of the parameters of the disturbed GMF. Special features of the GMF that were noted in terms of possibly strengthening the biologic effect included a power flux exceeding the level corresponding to the threshold sensitivity for a long time and abrupt jumps of energy and flux in the case of storms with sudden onsets.

- 5991 SOLAR ACTIVITY AND CARDIOVASCULAR DISEASES. (Eng.) Novikova, K. F. (Sverdlovsk Medical Inst., Sverdlovsk, USSR); Ryvkin, B. A. In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.): pp. 184-200; 1977. (34 refs)

A comparison of the frequency of cardiovascular disorders with some elements of solar activity and magnetospheric processes was conducted for several Soviet cities that are geographically far apart. The studies showed that there is an influence of heliogeophysical factors on the origin, course, and outcome of cardiovascular diseases. The percentage of myocardial infarction, morbidity and mortality, the frequency of hypertonic crises, attacks of stenocardia, cerebral insults, and mortality due to them were significantly higher on magnetically active days than on magnetically quiet days. With an increasing intensity of geomagnetic disturbances, the frequency of various cardiovascular disorders increased. The rates of incidence and mortality of cardiovascular diseases increased on days of magnetic storms and on the next 2 days thereafter, with a maximum occurring in the first 24 hr after the onset of

the magnetic storm. There was a tendency for cardiovascular disorders to arise on certain days of the 27-day calendar, which may indicate a solar origin of such a recurrence. The dynamics of cardiovascular disorders shows an 11-yr cycle, although to some extent this is concealed by the efficacy of modern treatment. In studying the influence of solar activity on the appearance of pathologic reactions in cardiovascular diseases, it is suggested that the gradient and tempo of variation in solar activity must be considered in addition to deviations from average values.

- 5992 SUDDEN DEATH FROM CARDIOVASCULAR DISEASES AND SOLAR ACTIVITY. (Eng.) Gnevyshev, M. N.; Novikova, K. F.; Ol', A. I.; Tokareva, N. V. (Main Astronomical Observatory, USSR Acad. Science, Moscow, USSR). In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.): pp. 201-210; 1977. (21 refs)

Data are presented correlating sudden death from cardiovascular diseases with solar activity and geomagnetic disturbances. An analysis of deaths from cardiovascular diseases in the city of Sverdlovsk during two 11-yr solar cycles (1944-1967) reveals a positive correlation between the frequency of such deaths and increased solar activity. Moreover, during the years 1961-1963, a marked peak in the curve for geoeffectiveness index was observed; this period was also marked by increased mortality due to cerebral insults (hemorrhages, thromboses), indicating the possibility of a joint action of some solar agent on both cardiac and cerebral deaths. The frequency of sudden deaths from cardiovascular diseases in Sverdlovsk was also correlated with geomagnetic disturbances for magnetic storms with gradual onset during the period 1955-1965. A correlation was also found between the dynamics of sudden cardiac death in Sverdlovsk and the total duration of bead type geomagnetic field oscillations. Active longitudes, where both the indexes of geomagnetic disturbance level and the number of sudden cardiac deaths were high, were observed along with a relationship between these phenomena. An analysis of clinical observations indicated that in periods of intensified geomagnetic activity, cases of sudden death were 2.7 times more frequent than in magnetically quiet periods. The largest number of sudden deaths occurred within the first 24 hr after the onset of a magnetic storm; however, the number of sudden deaths was also increased on the day when the storm was building up.

- 5993 TREATMENT OF SOME DISEASES WITH WEAK MAGNETIC FIELDS. (Eng.) Novak, J. (First Dermatology Clinic, Charles Univ., Prague, Czechoslovakia). In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.): pp. 229-231; 1977. (1 ref)

The effect of weak electromagnetic fields on humans is investigated to determine whether such fields

can be utilized for treating various diseases associated with nervous disorders. In some experiments a sheet metal cubicle (modified Faraday cell) with a 34-coil solenoid mounted inside it was used. The intensity of the direct current was 1-2 mA, which created a magnetic field of 40-80 gammas. In other experiments, a steel mesh helmet with a five-coil solenoid inside it was used. A current intensity of 1 mA was generated, which created a magnetic field of 280-480 gammas. The treatment consisted of leaving the patient in the cubicle for 90 min once a day for 10 days. An effect was already apparent after 5 days, and maximum results were obtained 2 wk after the end of treatment. The effect of the treatment usually lasted for 3-6 mo, and in a number of cases longer. If a relapse occurred, the treatment was repeated. In controlled experiments involving a total of 141 patients with diagnoses of urticarial fever, other allergic dermatoses, skin edema, photodermatoses, bronchial asthma, neuralgia, epilepsy, and stenocardia, cures were obtained in 41 patients, considerable improvement in 50 patients, improvement in 27 patients, and no change in 23 patients. The experiments show that weak magnetic fields of the same magnitude as those naturally occurring on the earth under the influence of solar corpuscles probably have an effect on meteorolabile persons.

- 5994 THE MECHANISM OF THE INFLUENCE OF SOLAR ACTIVITY OSCILLATIONS ON THE HUMAN ORGANISM. (Eng.) Osipov, A. I.; Desyatov, V. P. (Tomsk Medical Inst., Tomsk, USSR). In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.): pp. 232-237; 1977. (5 refs)

Studies on the influence of solar activity and magnetic fields on the human organism are reviewed. At the Institute of Higher Nervous Activity and Neurophysiology of the USSR Academy of Sciences, it was demonstrated that magnetic fields can inhibit the formation of conditioned reflexes. All divisions of the brain react to artificial magnetic fields, but the cortex and hypothalamus are the most responsive. A comparison of cases of sudden death from cardiovascular diseases with sharp oscillations of the geomagnetic field (magnetic storms) over the period July 1958 to 1966 revealed that on the average there were 0.33 cases of death on the day of a magnetic storm and on the first day after, while there were only 0.22 cases of sudden death on magnetically quiet days. When the influence of domestic factors on the results was eliminated, the average mortality on days with magnetic storms was almost twice as high as on quiet days; the statistical difference was significant at the 0.1% level. Studies on automobile accidents between the years 1958 and 1964 indicated that the number of such accidents was almost four times as high on the first day after a solar flare as on quiet days. This difference was statistically significant on the day of the flare (0.1% level) and on the two following days (0.1% and 5% levels, respectively).

- 5995 SOLAR ACTIVITY AS A WEIGHTY FACTOR IN ROAD ACCIDENTS. (Eng.) Masamura, S. (Div. Culture and National Education, Nagoya, Japan). In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.): pp. 238-240; 1977. (0 refs)

The incidence of road accidents in Japanese cities is compared with solar activity over various time spans to determine if there is a correlation. When the number of road accidents in Tokyo and in Japan as a whole from 1943 to 1965 was compared with the Wolf number variation in solar activity during the same years, good agreement was seen between the curves for these parameters. When the number of road accidents in 10 Japanese cities between July 1 to July 15, 1966 was examined (a solar flare was observed on July 7), it was found that there was a substantial increase in road accidents during this period. The number of accidents rose immediately after the flare and also coincided with an increase in the sunspot area, both in the central zone and on the entire disk. An examination of individual cases of increases in the number of road accidents shows that they often coincide with magnetic storms, another manifestation of solar activity. It is suggested that the correlation between solar activity and road accident frequency derives from the influence of oscillations of the geomagnetic field on the human nervous system.

- 5996 THE DISTURBANCE LEVEL OF THE GEOMAGNETIC FIELD AND THE MOTOR ACTIVITY OF INSECTS. (Eng.) Chernyshev, V. B. (Dept. Entomology, Moscow State Univ., Moscow, USSR). In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.): pp. 247-258; 1977. (12 refs)

Observations of the flight of different insects toward light and multidiurnal recordings of the motor activity of one species of beetle in the laboratory are analyzed to determine if a correlation exists between solar activity and insect behavior. An analysis of the correlation between the number of insects caught in a light trap during a given night and the characteristics of the magnetic activity for that day was performed for five randomly chosen geographic locations. A correlation between the number of insects caught in one night and the diurnal characteristics of geomagnetic activity was detected for all but one of the locations. The significance of the correlation always increased when meteorologic factors were also taken into account. In no case was there a correlation with magnetic disturbance level in the course of the collection night alone; rather, nocturnal flight was always affected by disturbances of the geomagnetic field occurring earlier in the day. Multidiurnal recordings of the motor activity of the Khapra beetle, *Trogoderma glabrum herbat*, were made in the laboratory to study the correlation of rhythmic indexes with

five-point magnetic characteristics of certain days and with ten-point relative magnetic characteristics for the periods 18:00-21:00 hr, 21:00-24:00 hr, and 00:00-03:00 hr, Moscow time. The laboratory observations confirmed the correlation observed between insect motor activity and disturbance levels in the geomagnetic field.

- 5997 AN EXPERIMENTAL STUDY OF THE EFFECT OF ULTRALOW-FREQUENCY ELECTROMAGNETIC FIELDS ON WARMBLOODED ANIMALS AND MICROORGANISMS. (Eng.) Vladimirov, B. M.; Volynskii, A. M.; Vinogradov, S. A.; Brodovskaya, Z. I.; Temur'yants, N. A.; Achkasova, Y. N.; et al. In: *Effects of Solar Activity on the Earth's Atmosphere and Biosphere*. Hardin, H., ed. (Jerusalem: Keter Publishing House Jerusalem Ltd.): pp. 259-269; 1977. (13 refs)

The effect of ultra-low-frequency electromagnetic fields on rabbits and dogs as well as on various types of microorganisms was studied. Alternating electromagnetic fields (AEF) in the frequency range from 0.1-8 Hz at low field strengths proved to be biologically active. In all of the animals investigated, there was a change in the systolic rhythm as well as in bioelectric phenomena in the heart characterizing changes in the system producing excitation in the heart. Dynamic changes occurred in the electrical activity of the cortex, and distinctive dynamic changes occurred in the blood. Under the influence of AEF, peroxidase was found to be inactivated, with the degree of enzyme inactivation depending on the field strength. The effect of inactivation was observed at field strengths close to those under natural conditions during violent magnetic storms. Anatomopathologic examinations revealed some destructive changes in the heart and lung tissues. Microorganisms were found to react to AEF by more intensive multiplication and by nonhereditary changes of morphological and cultural properties. The above results may be considered as experimental confirmation of the hypothesis concerning the ecologic role of natural AEF controlled by solar activity.

- 5998 SURVEY OF MICROWAVE AND RADIOFREQUENCY BIOLOGICAL EFFECTS AND MECHANISMS. (Eng.) Cleary, S. F. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 16-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. A0 A051218): pp. 1-33, 1978. (72 refs)

Selected literature on the neuroendocrinologic, hematopoietic, and neural effects of microwave radiation is reviewed, with special emphasis on effects reported at intensities of 10 mW/cm² or less. The weight of scientific evidence that has accumulated during the past few years lends credence to the hypothesis that low intensity microwave and radio frequency fields can in some cases result in physiologic and psychologic al-

terations. These alterations have generally been reported to be reversible, and the effects are in many cases induced at intensities that may be associated with low level thermal stress. In experiments in which the effects of radiation heating and nonradiation heating on specific biologic endpoints have been compared, more pronounced effects are usually induced by exposure to electromagnetic fields, and in some instances, decided qualitative differences have been detected. The extent to which such differences may be attributed to variations in the heating patterns and/or heating rates is not evident at this time due to insufficient data. The rather consistent finding that pulse or amplitude-modulated microwave and radio frequency fields produce more profound alterations in living systems as well as the rather limited data on the frequency dependence of such effects suggests that physical interactions other than those resulting in generalized heating may be involved in low intensity field effects in biologic systems. The most likely interaction mechanism appears to involve macromolecular assemblages stabilized by long-range systems of weak time-varying cooperative interactions. Taken with the experimental data on low intensity field effects, it may be suggested that biomembranes may be the primary site for microwave or radiofrequency alterations.

- 5999 MOLECULAR ABSORPTION OF NON-IONIZING RADIATION IN BIOLOGICAL SYSTEMS. (Eng.)
Straub, K. D. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 35-42, 1978. (23 refs)

The absorption of nonionizing electromagnetic radiation in biologic systems is discussed in terms of bulk dielectric properties of living tissues and in terms of the biologic function of the molecular species absorbing energy. The bulk dielectric properties of biologic material have been under investigation for over 50 yr. The dielectric constants of the molecular constituents of living cells and the complicated assembly of cells and organs have been measured at frequencies from below 100 Hz to over 10 GHz. The dispersions of dielectric constant with frequency seen in various tissue and cellular suspensions can be understood in terms of certain specific relaxation mechanisms. While the bulk dielectric constants of living matter can be fairly well understood, other more highly specific absorptions of electromagnetic radiation may be important. Examples of such are the following: the maintenance of adiabatic conditions in small membrane-bound volumes for long periods of time, subsequent temperature elevations and their effects on membrane structures or on complex protein assemblies, the rotation or translation of molecules in mitochondria

and ribosomes by electromagnetic radiation, the influence of electromagnetic radiation on proton tunneling with resulting isomerization of deoxyribonucleic acid base pairs, and electromagnetically-induced forced oscillation of the otherwise random motion of gates in excitable channels of nerve membranes with resultant membrane depolarization. Further analysis should include consideration of the behavior of membranes as thin films, the existence of electrically ordered domains within the cell or at the membrane, and the restrictions on relaxation mechanisms due to the finite small size of the molecular structures of the cell.

- 6000 MILLIMETER WAVE AND FAR INFRARED ABSORPTION IN BIOLOGICAL SYSTEMS. (Eng.)
Illinger, K. H. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 43-66, 1978. (60 refs)

Interactions of millimeter wave and far infrared radiation with biologic systems are discussed. Recent formal theoretic work, which was tentatively supported by experimental findings, suggested that a crucial aspect of the electromagnetic field interaction of biologic systems in the millimeter wave and far infrared region might lie in the existence of long-range collective molecular interactions within membranes associated with coherent electromagnetic oscillations in this frequency regime and result in coupled biochemical reactions (e.g., enzyme-substrate interactions) with extremely-low-frequency (10-100 Hz) oscillatory kinetics. A direct corollary of the analysis of the coherent regime spectra of biologic systems is the relationship of such spectra with cell type and type of substrate-interactant system. Under favorable conditions, differentiation of cell type and reaction type might be achieved, permitting the use of spectroscopic technique for the diagnosis of cell type and function. Differentiation between normal and tumor cells has been claimed in the literature. It is further possible that intervention in the collective mode chemical reactions involving metastable states (with coherent modes) via millimeter wave electromagnetic radiation may have therapeutic as well as diagnostic implications. Conversely, if such controlled biomedical applications are possible, it is a requisite to inquire into possible bioeffects and health implications of technologic electromagnetic radiation in the coherent regime frequency region. Several technologic applications must be considered in this context: multichannel millimeter wave communications systems, millimeter wave high-resolution radar, and microwave power transmission along terrestrial and proposed satellite-based transmission routes through the earth's atmosphere.

- 6001 SOME BASICS OF ELF FIELDS AND THEIR BIOSPHERE EFFECTS. (Eng.) Schmitt, O. H. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 71-74, 1978. (0 refs)

The significance of possible biologic effects of extremely low frequency (ELF) electromagnetic fields is discussed, and the results from one particular experiment are reported. It is difficult to design workable, reasonably economical, and ethically acceptable experimental procedures to determine whether some of the suspected subtle ELF effects are real, experimental artifacts, or merely statistical accidents. One experiment was designed to determine whether humans can consciously perceive at a statistically significant level the presence or absence of a moderate strength, low-frequency magnetic field. The ability of these subjects to learn by biofeedback training to perceive such fields was also examined. In general, the subjects did not appear to perceive or to learn to perceive such fields. A few individuals proved to be incredibly skillful in extracting relevant hints from diverse environmental signals such that they put together in a self-taught synthesis subtle subliminal leakages of informational clues. It is concluded that moderate level ELF fields have little direct adverse effect on biologic systems but that they may possibly play a role by intruding competitively into a multivariate filled-channel communication and control system that is more and more frequently found to operate, especially in highly organized biologic organisms and systems.

- 6002 POSSIBLE MECHANISMS OF WEAK ELECTROMAGNETIC FIELD COUPLING IN BRAIN TISSUE. (Eng.) Bawin, S. M.; Sheppard, A.; Adey, W. R. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 75-90, 1978. (22 refs)

The effects of weak electromagnetic fields on calcium efflux from chick and cat cerebral tissue are investigated. The data strongly suggest that the binding and release of calcium occurs cooperatively as a result of long-range interactions between anionic charge sites on the binding substrate. Extremely low frequency fields at frequencies of 6 and 12 Hz and gradients in air of 0.1-0.5 V/cm decreased calcium efflux by 12-15%. Higher and lower frequencies were without significant effect. For chick tissue, the field threshold in air was 0.1 V/cm and for cat tissue, around 0.6 V/m. At intensities above and below these levels, the effects became sta-

tistically insignificant. With 147-MHz amplitude-modulated fields, calcium efflux from chick cerebral tissue increased for modulation frequencies from 6-20 Hz, with the maximum efflux increase being more than 15%. No significant changes occurred at higher or lower modulation frequencies or with an unmodulated carrier wave. With 450-MHz fields, amplitude modulated at 16 Hz, increased calcium efflux from chick cerebral tissue occurred at field intensities between 0.1 and 1.0 mW/cm². No increase was noted above or below these levels. It is hypothesized that membrane surface charge sites behave coherently over a considerable area and that a coherent patch may be triggered to change state by a very weak trigger at one point. This triggering event may involve proton tunneling at the boundary of such a patch.

- 6003 CLASSICAL THEORY OF MICROWAVE INTERACTIONS WITH BIOLOGICAL SYSTEMS. (Eng.) Schwan, H. P. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 91-112, 1978. (54 refs)

Mechanisms responsible for the interaction of microwaves and other electrical fields with biologic systems are reviewed. Heat development, which is caused by the absorption of microwave energy, is mathematically related to the electrical field strength and the electrical conductivity of the absorber. Various contributions to the total conductivity are analyzed for ions, water, biopolymers, bound water, and lipids. The ionic contribution is frequency independent and has a value of approximately 10 mmho/cm for abundant tissues with high water content and frequencies above about 0.1 GHz. All other contributions are frequency dependent and can be represented by either a single or a sum of Debye expressions. The volume specific absorption rate, as expressed by electrical conductivity, is shown to be greatest for electrolytes up to a frequency of about 0.5 MHz. Water dominates above 4 or 5 MHz. Bound water may be the major absorber between 0.4 and 4 GHz. Ionic contributions and water clearly dominate over the total frequency range, and biopolymer and protein-bound water contribute only insignificantly to the total absorption of energy. Direct field interactions with various biocomponents are also considered. These include membrane interactions, biopolymer interactions, interactions with biologic fluids, and field-generated forces manifested by orientation, pearl chain formation, deformation, movement, and destruction.

- 6004 DETERMINATION OF BOUND WATER IN BIOLOGICAL MATERIALS FROM DIELECTRIC MEASUREMENTS. (Eng.) Grant, E. H. In: *The Physical Basis of Electromagnetic Interactions with*

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Using a spherical shell model for the macromolecule and experimentally determined permittivities and conductivities, variation in specific energy absorption was calculated as a function of the frequency of electromagnetic energy. The calculation indicated that a frequency region exists where the absorption of energy per unit volume of bound water is considerably greater than that of free water; this frequency region occurs around 1.0 GHz. For biologic materials that have a large bound water content (such as lens tissue) this finding could be of consequence in evaluating microwave radiation hazards, particularly if an attempt is made to build a frequency factor into the maximum recommended power levels for personnel exposed to microwaves. The importance of the finding is further enhanced when it is considered that bound water is immediately adjacent to the vital biologic macromolecules.

6005 INTERFACIAL AND INTRACELLULAR WATER: EXPECTED ANOMALIES IN DIELECTRIC PROPERTIES. (Eng.) Clegg, J. S.; Drost-Hansen, W. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 121-131, 1978. (31 refs)*

The anomalous structure of intracellular water is discussed in relation to the nature of interactions of microwaves with biologic systems. Such water appears to be structurally different from bulk water and, as a consequence, is expected to possess dielectric properties distinctly different from bulk water. Unusual properties of vicinal water, which may be of interest in connection with microwaves, include the enhanced thermal conductivity and the unusual heat capacity of vicinal water. It is suggested that it is reasonable to expect that such water, compared with bulk water, may exhibit decidedly different properties in high frequency electromagnetic fields. Calculations of the amount of intracellular surface area of rat liver cells that perturb water suggest that at least 50% of the total water in these cells must be sufficiently perturbed, due to direct solvation or proximity to a surface, and that its properties should differ significantly from neat water. Inasmuch as the status and disposition of intracellular water are important to the interpretation and understanding of the interactions of electromagnetic radiation with biological systems, it may be useful to consider the vast internal

surface areas of cells and their ability to perturb water that is proximal to them.

6006 MICROWAVE FREQUENCIES AND THE STRUCTURE OF THE DOUBLE HELIX. (Eng.) Prohofsky, E. W. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 133-144, 1978. (8 refs)*

Calculations of vibrational modes of homopolymer deoxyribonucleic acid (DNA) double helices are discussed in relation to the microwave frequency spectrum. Using force constants refined by comparison with infrared and Raman lines, calculations were made of the vibrational modes of the double helices. The results indicated a number of bands within the microwave region of the spectrum. In the case of the B to A conformation change of double helical DNA, the mode of interest, which drove the conformation, was calculated to be at 0.3 cm^{-1} ; this is roughly 10^{10} Hz . It is suggested that the frequency of modes of structural importance are low enough to be affected by electromagnetic radiation and that several modes, which exist at higher frequencies, may be involved in similar dynamic roles. Pumping on these modes can cause instabilities that can affect function. Microwave absorption, which is a transfer of energy from a microwave field to the vibrational modes of these macromolecules, may also alter the interaction of modes that modify instabilities driven by other phenomena.

6007 TECHNIQUES OF RAMAN SPECTROSCOPY APPLIED TO STUDY THE EFFECTS OF MICROWAVES UPON SYNTHETIC AND NATURALLY OCCURRING PHOSPHOLIPID MEMBRANES (MEETING ABSTRACT). (Eng.) Sheridan, J. P.; Priest, R.; Schoen, P.; Schnur, J. M. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 145-148, 1978. (0 refs)*

The effects of continuous wave and pulsed microwave radiation on synthetic and naturally occurring phospholipid membranes were studied using Raman spectroscopy. Single component, binary mixtures, and naturally occurring bovine material were systematically characterized as a function of temperature using Raman scattering to provide information about the phase diagram and the order of lipids within the membrane. These characterized materials were then studied under microwave irradiation. Preliminary results show lipid chain disorder induced by 2-GHz microwave radiation at a power density of approximately 10 mW/cm^2 . These

effects were observed in naturally occurring bovine sphingomyelin materials and were most pronounced in the biologically interesting temperature region of 32-37 C.

- 6008 EVANESCENT WAVES AND WAVES IN ABSORBING MEDIA. (Eng.) Felsen, L. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 149-163, 1978. (1 ref)

The application of high frequency evanescent waves to problems involving the diagnostics of dielectric materials is discussed, with emphasis being primarily on new techniques that have been developed for the propagation of fields in lossless materials. Conventional types of evanescent fields arise, for example, when radiation is guided inside a dielectric layer. The fields are trapped by total reflections and are therefore evanescent wiggly arrows on the outside of the layer. The tracking of evanescent waves is done along the phase paths. From the geometry (spreading or contracting) of phase paths, the complete characteristics of the local field can be constructed by subsequent integration. Conversely, by monitoring the phase and amplitude of a field as it traverses a material medium, whether it be a beam field or an ordinary plane wave field, an inverse process can be used to reconstruct the characteristics of the medium through which the field has passed. Although the methods of evanescent fields are applied primarily to lossless media, the basic attributes of complex phase make these techniques relevant also to fields in lossy media.

- 6009 MICROWAVE AND RF DOSIMETRY. (Eng.) Chou, C.-K.; Guy, A. W. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 165-216, 1978. (43 refs)

Factors that determine microwave or radio frequency (RF) power absorption are discussed along with techniques for measuring incident power density and specific absorption rates. Factors that determine microwave and RF power absorption in tissue at the same incident power density include tissue dielectric properties, tissue geometry, tissue size, the frequency of the electromagnetic field, polarization of electromagnetic fields, source geometry and size, the surroundings of the exposed object, and artifacts produced by metal implants. Instruments used for incident power density measurements include the Narda 8100

Series survey meter, the Narda 8300 Series broad band survey meter, the NBS meter, the Golay cell probe, the BRH electric field probe, pyroelectric probes, and magnetic field probes. Techniques for specific absorption rate measurements include a glass probe and thermocouple combination, a fiber-optic liquid crystal probe, a thermistor with high resistance leads, other temperature probes using such devices as birefringent crystals and optical etalons, microwave diodes, thermography, twin-well calorimetry, and waveguide systems. The application of dosimetric techniques is illustrated for a rabbit head exposed to a 2,450-MHz diathermy C director, a rabbit exposed to an approximate plane wave field, a cat exposed to a 918-MHz aperture source, a rat exposed to a 918-MHz aperture source, and a phantom man exposed to simulated 31-MHz RF fields in a cavity. Studies of the coupling of 918-MHz microwave oven door leakage to human subjects, of animals exposed to 500-MHz electromagnetic energy in cavities, and of specific absorption rates in a waveguide chronic exposure system are also reviewed.

- 6010 ELECTRIC FIELD MEASUREMENTS WITHIN BIOLOGICAL MEDIA. (Eng.) Cheung, A. Y. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 217-242, 1978. (9 refs)

A miniature isotropic electric field probe developed by the BRH for implantation type electric field measurements in biologic tissues is described. The probe consists of an array of three orthogonal, electrically short dipoles (2.5 mm in length), each coated with a thin layer of epoxy. Each dipole contains a microminiature beam lead diode detector chip placed directly across the center gap of the antenna. High resistance, thin film leads allow the detected voltage to be monitored by a high impedance direct current amplifier without perturbation of the field under study due to microwave current flow in these leads. The experimental and theoretical response of the probe in muscle tissue agreed within $\pm 10\%$ when the free space probe sensitivity coefficient was directly used. It is concluded that once calibrated in free space, this probe can be used for accurate measurements of electric fields within infinite slabs of muscular tissues. The response of the probe can be equated with the actual electric field strength existing in muscular tissue at frequencies ranging from 0.915-2.45 GHz by simply using the free space calibration factor for the probe. Problems associated with measurements performed in biologic systems near the boundary layers between various biologic materials were also considered. Worst case (muscle-air) boundary conditions were experimentally measured with continuous scans along an

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axis normal to the boundary plane. The experimental findings demonstrated that no detectable probe-boundary interaction occurred during increasing proximity to the boundary. This is unique to the specific probe design utilized in which the diode detector impedance is much higher than the antenna impedance, thus eliminating dipole-boundary interactions. The lack of significant electric field perturbation by the probe itself was also demonstrated in a muscle-equivalent slab.

- 6011 SOME RECENT RESULTS ON THE DEPOSITION OF ELECTROMAGNETIC ENERGY IN ANIMALS AND MODELS OF MAN. (Eng.) Gandhi, O. P.; Haggmann, M. J. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 243-259, 1978. (15 refs)

The results of studies on electromagnetic deposition in realistic human models and in animals are reported. A total of 180 cubical cells of various sizes were used to obtain a best fit of the contour on diagram of the 50th percentile standard man. Use was made of the moment method solution of the electric field integral equation with a pulse function basis and delta functions for testing. Unlike earlier numeric models, both the average absorption and the distribution of absorbed energy within the model were in good agreement with experimental measurements made using phantom models. The distribution of absorbed energy was found to be frequency dependent and was explained in terms of resonant frequencies for various parts of the body. Numeric solutions for man near a ground plane and near reflectors were also obtained. At a frequency of 10 MHz, the specific absorption rate of a man standing on a ground plane was calculated as 0.0163 W/kg per mW/cm², which is about seven times that found for the same model in free space. At 65 MHz, the computed specific absorption rate was 4.87 times the free space value when a man is 0.1875 wavelengths in front of a flat reflector and 16.6 times the free space value when a man is 1.5 wavelengths in front of the axis of a 90-degree corner reflector. Preliminary experiments with adult rats have confirmed the existence of multibody effects. For two animals placed 0.65 wavelengths apart, the average temperature increase in the monitored animals was 1.14 C/min compared with 0.675 C/min for isolated animals exposed to 600 MHz at an incident intensity of 100 mW/cm². Therefore, a 70% increase in the specific absorption rate was caused by the presence of the second animal.

- 6012 THERMOMETRY IN STRONG ELECTROMAGNETIC FIELDS. (Eng.) Cetas, T. C. In: *The Physical Basis of Electromagnetic Interactions*

with Biological Systems: *Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 261-281, 1978. (39 refs)

New developments in thermometry designed to meet the need for measurements in the presence of strong electromagnetic fields are reviewed. Thermometer probes designed for use in electromagnetic fields include those employing liquid crystals, a liquid meniscus, an optically birefringent crystal, an optical etalon, semiconductor optical absorption, thermistors, and the property of fluid viscosity. Five of these designs avoid electromagnetic absorption and reflection effects by using optical fibers rather than electrical conductors. Two others use thermistors as sensors and reduce the electromagnetic interactions through very high lead resistivities to minimize dipole currents and small enclosed loop areas to reduce magnetically induced currents. Another uses the viscosity of a fluid as the sensitive parameter and bypasses electromagnetic interactions. Only one of these minimally perturbing probe thermometers is presently commercially available. It is a liquid crystal-optical fiber type probe. Two optical fiber bundles carry light from the source (a red light-emitting diode) to the sensor and from the sensor to a photodetector (a photodiode). The sensor tip is composed of a liquid crystal mixture, which exhibits strong temperature dependence in its reflectance of red light. Various temperature ranges of about 14 C can be selected by varying the liquid crystal mixture. A precision of 0.1 C is quoted. Also discussed are requirements for calibration facilities, probe thermometers, and thermographic systems. It is suggested that if a thermographic camera is calibrated and if proper account is taken of the radiometric properties of the source, then reliable temperature measurements can be made within the noise specifications of the instrument.

- 6013 NON-PERTURBING MICROPROBES FOR MEASUREMENTS IN ELECTROMAGNETIC FIELDS. (Eng.) Deficis, A.; Priou, A. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 283-293, 1978. (7 refs)

A non-interfering dielectric microthermometer probe for making temperature measurements in electromagnetic fields is described. The microthermometer operates over a temperature range of -40 to +150 C, has a sensitivity of about 0.5 C, and has a response time of less than 15 sec. The principle of probe operation is based on the reflection of a light beam by a thermodilatable liquid contained in a capillary glass pipe of small

dimensions. In the glass pipe, the liquid forms a concave reflector meniscus. The quantity of liquid is very small; therefore, the probe thermal inertia is low, and the temperature readout is rapidly accomplished without any disturbance of the medium. Measurements with such a probe in electromagnetic fields ranging from 900-915 MHz, 2,400-2,500 MHz, and 8.2-12.4 GHz indicate that the perturbation caused by the thermometer is very low (less than or equal to 0.1 dB) whatever the orientation of the probe in terms of the electric field. Further, the voltage standing wave ratio due to the probe is less than 1.1:1.

- 6014 THE VISCOMETRIC THERMOMETER. (Eng.) Cain, C. A.; Chen, M. M.; Lam, K. L.; Mullin, J. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 16-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 295-308, 1978. (14 refs)

A viscometric thermometer that can be used for temperature measurement in electromagnetic wave environments, such as those encountered in microwave- or radio frequency-induced hyperthermia, is described. The thermometer is based on the measurement of temperature-dependent viscosity of a fluid flowing through a small sensing capillary in the probe tip. Since the change in viscosity of most liquids is in the range of percents per degree Celsius, very high temperature sensitivities are possible. A large number of pumping and measuring arrangements can be made to measure the flow resistance and, indirectly, the viscosity in the probe tip. These include a constant flow pump with measurements of the pressure difference, a constant pressure rise pump with measurements of flow, and systems representing intermediaries of these two examples. Advantages of the viscometric thermometer over other existing temperature measurement techniques include thermal and mechanical stability, the minimizing of electrical and thermal perturbations, and simplicity of operation.

- 6015 MICROWAVE THERMOGRAPHY: PHYSICAL PRINCIPLES AND DIAGNOSTIC APPLICATIONS. (Eng.) Myers, P. C.; Barrett, A. H. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 16-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 309-325, 1978. (19 refs)

The physical principles and diagnostic applications of microwave thermography are discussed. Microwave thermography is possible because human tissue emits thermal radiation whose intensity at microwave frequencies is proportional to tissue temper-

ature. Several medical problems, including cancer, are accompanied by local changes in temperature of the order of 1 C. Present day radiometers can detect intensity changes corresponding to emitter temperature changes of less than 1 C. Specific tissue model studies of microwave penetration depth indicate that at 3 GHz the penetration depth is 5 cm (about 1 tissue wavelength) in fat and 0.8 cm in muscle or skin. The penetration depth decreases with increasing frequency. At frequencies above 10 GHz, escaping thermal emission originates in a skin layer less than 1 mm deep. This suggests that thermography at millimeter wavelengths may be expected to give results very similar to those of infrared thermography. For a rectangular waveguide antenna in direct contact with the skin surface, the thermographic antenna response pattern is a combination of the near- and far-field patterns of each aperture dimension. The response pattern resembles a funnel whose cone opens away from the antenna with a half angle of about 50 degrees. A 3.3-GHz radiometer is described that has a temperature sensitivity of approximately 0.1 C for an integration time of 6 sec. During data taking, the antenna aperture is placed flush against the skin to eliminate reflective loss at the tissue-air interface and to permit minimum spatial resolution for the given antenna size. Potential medical applications of microwave radiometry include the detection of subsurface thermal anomalies, such as, malignant tumors, localized inflammations, and vascular insufficiency in the limbs and in the brain. Studies with the use of 3.3-GHz microwave thermography for detecting breast cancer indicate true positive and true negative rates slightly inferior to those of infrared thermography. In combination with infrared thermography, microwave thermography yields true positive rates in excess of 90%, and there is no radiation exposure risk as with mammography.

- 6016 DESIGN AND STANDARDIZATION OF EXPOSURE SYSTEMS FOR RF AND MICROWAVE EXPERIMENTATION. (Eng.) Swicord, M. L.; Ho, H. S. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 16-17, 1977*. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 327-358, 1978. (32 refs)

Currently used microwave and radio frequency (RF) animal and cellular exposure systems are described. The better exposure systems presently in use define either external unperturbed fields or absorbed dose and have provided fairly well-defined exposure levels at which biologic effects have been observed. Types of exposure systems discussed include free space whole body exposure systems using anechoic chambers, parallel plate transmission line animal exposure systems, waveguide animal exposure systems, cellular exposure systems, and selective exposure systems using dielectric lens, RF cavity exposure, or microwave waveguide/cavity exposure. It is

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suggested that there is a need for the design of exposure systems that will aid in determining biophysical mechanisms rather than demonstrating the existence of biologic effects of microwave radiation. Biologic considerations may dictate either selective or whole body exposure. In either case, the standard universal exposure system does not exist. There are, however, standard procedures and measurements that should be incorporated. First, temperature and humidity should be controlled and held at a fixed agreed-upon value unless variation is desired or other extenuating circumstances exist. These parameters could be appropriately 28 C and 40% humidity for whole body exposure and 37 C for cell exposure. Secondly, internal fields throughout the exposed animal or cell system should be described through measurement or calculation so that an appropriate comparison of experimental results can be made. Hypotheses concerning mechanisms can only be tested if a detailed knowledge of energy deposition exists. Thirdly, the exposure field characteristics of frequency and modulation must be monitored and controlled.

- 6017 CALIBRATION TECHNIQUES FOR MICROWAVE AND RF EXPOSURE MEASUREMENT DEVICES. (Eng.) Bassen, H. I. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 359-382, 1978. (11 refs)

Plane wave (far-field) and guided wave calibration techniques for microwave and radio frequency devices are described. One technique, which is most suitable above a frequency of 500 MHz, utilizes an anechoic chamber and waveguide horn antennas. In BRH plane wave calibration systems, extensive use is made of the power equation techniques developed by the NBS, allowing the basic quantities of power and mismatch in a waveguide to be transferred to the calibration of radiated power. Accurate measurement of the path loss between two truncated waveguide horn antennas is performed in an anechoic chamber, facilitating antenna gain determination. A high power directional coupler in series with the transmitting antenna is calibrated to allow absolute transmitted power to be monitored. A small isotropic probe may be placed at a point in the chamber and calibrated using a television camera with a telephoto lens to observe the instrument's indicated power density. The evaluation of multipath reflections and other error sources allows the precise prediction of plane wave power density at this specific point in the chamber. Below a frequency of 500 MHz, serious problems occur when probe calibration is attempted via the free space, power density methods involving horn antennas, and an anechoic chamber. An accurate and convenient guided wave system has been developed by the NBS. This system utilizes a rectangular transverse electromagnetic mode (TEM)

transmission line cell. The TEM cell consists of a rectangular metallic outer enclosure, a flat, wide center conducting strip, and tapered input and output feed sections, which maintain a 50-ohm characteristic impedance throughout the transmission line. This rectangular coaxial line has been thoroughly analyzed, both theoretically and experimentally, and has been developed into a commercially available product. Advantages of the TEM cell are that it can be used to generate electric and magnetic fields with an absolute uncertainty of approximately ± 1 dB below 500 MHz and that it does not require either high power generators (greater than 100 W) or a large amount of physical space.

- 6018 WORKSHOP SUMMARY. (Eng.) Cleary, S. F. In: *The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 383-395, 1978. (0 refs)

Contributions to a workshop on the physical interaction mechanisms of electromagnetic fields with biologic systems are summarized. The topics discussed at the workshop included the development of dosimetry and calibration methods and techniques for quantitating electromagnetic fields; the necessity for accurately measuring field intensities, electric field strengths, and temperatures in tissues; the design and standardization of exposure systems for radio frequency and microwave experimentation; recent results on the deposition of electromagnetic energy in animals and models of man; the relationship of energy absorption, radiation frequency, and polarization to the geometric characteristics of biologic absorbers; the use of Raman spectroscopy for studying the effects of microwaves on phospholipid membranes; the effects of microwaves on biologic macromolecules; the use of dielectric measurements in studying electromagnetic interactions with biologic systems; possible mechanisms of weak electromagnetic field coupling in brain tissue; millimeter wave and far infrared absorption in biologic systems; and a survey of microwave and radio frequency biologic effects and mechanisms.

- 6019 RADIATION EMISSIONS FROM NEW MOBILE COMMUNICATION SYSTEMS. (Eng.) Lee, A. M.; Baldwin, B.; Frey, J. In: *Communications for a Mobile Society: An Assessment of New Technology.* Bowers, R.; Lee, A. M.; Hershey, C., eds. (Beverly Hills: Sage Publications): pp. 275-292; 1978. (51 refs)

Potential hazards associated with nonionizing radiation emissions from 900-MHz mobile communication systems are reviewed. It is concluded that the power radiated by 900-MHz mobile communication systems will not create field intensities that are

large enough to be a substantial hazard. It is estimated that in an extremely high use situation with a congested urban market, new 900-MHz mobile communication systems could contribute something less than $1 \mu\text{W}/\text{cm}^2$ of radiation in particular parts of cells. This density is roughly equivalent to the emissions from a strong frequency-modulated (FM) radio station at a distance of 2,500 m. While exactly how much the ambient level will rise in response to a high deployment of mobile communication technology cannot be determined exactly, it can be concluded that the new level will be five orders of magnitude less than intensities that cause thermal damage (i.e., $100 \text{ mW}/\text{cm}^2$) and well below the safety standard of $10 \text{ mW}/\text{cm}^2$. Moreover, this average calculated ambient level is below the much more stringent nonoccupational standard recommended by Soviet authorities. Users of portable, hand-held equipment might be exposed to significant amounts of radiation independent of deployment levels. Though the very localized density may be on the order of a few milliwatts per square centimeter, certain body organs in close proximity to the emitter may nevertheless be affected. The essentially avascular middle ear may be affected by microwave power densities as low as $2 \text{ mW}/\text{cm}^2$. Given the uncertainties of the biologic effects of nonionizing radiation and the fact that local radiation levels may depart substantially from average ambient levels, it seems prudent to incorporate some monitoring devices into new systems as they are deployed.

MEETING ABSTRACTS

- 6020 MIGRATION OF ERYTHROCYTES AND THEIR SEPARATION INTO FRACTIONS INDUCED BY MAGNETIC FIELDS (MEETING ABSTRACT). (Eng.) Porath, A. (Dept. Biological Chemistry, The Hebrew Univ., Jerusalem, Israel). In: *Abstracts of the VIth Engineering Foundation Conference on Automated Cytology held in Schloss Elmau, Bavaria, West Germany, April 23-29, 1978. Plenary Session 7; 1978.* (0 refs)

Suspended and chemically reduced erythrocytes in weak magnetic fields flock along the edges of the magnetic poles. This aggregation occurs during the spontaneous sedimentation of the cells by the force of gravity above a magnet, or when the sedimentation was previously completed and the magnetic field was applied later. When erythrocytes in a container were allowed to form a sediment layer on the bottom, and a rotating magnetic field

was later maintained in the layer, the formation of cell aggregates was observed. These aggregates tended to stick together to form one single lump that exhibited ferromagnetic behavior. When a rotating magnetic field was applied to an erythrocyte suspension in such a way that an elongated, horizontal container was tangential to the rotating magnet, the cell suspension became separated from the medium with an "S"-shaped boundary between them. The boundary was found to move in the direction of the magnet's rotation. Parallel to the boundary and above it, a separate low-density cell cloud formed and followed the boundary's movement. The cells sedimented slowly during the treatment to the bottom of the container causing the boundary to move. The low density cell cloud moved together with it, and since it was formed of cells with lower specific gravity, it was the last to sediment.

- 6021 CYTOFLUORIMETRY OF ELECTROMAGNETICALLY CONTROLLED CELL DE-DIFFERENTIATION (MEETING ABSTRACT). (Eng.) Chiabrera, A.; Hinsenkamp, M.; Pilla, A. A.; Ryaby, J.; Belmont, A.; Beltrame, F.; et al. (Univ. Genoa, Genoa, Italy). In: *Abstracts of the VIth Engineering Foundation Conference on Automated Cytology held in Schloss Elmau, Bavaria, West Germany, April 23-29, 1978. Poster Session I(15); 1978.* (0 refs)

De-differentiation was produced in vitro in nucleated red blood cells of frogs by magnetically inducing an alternating current electric field and by modifying the ionic concentration of the isotonic Ringer medium. The cells were stained by fluorochrome acridine orange (AO), so that the green fluorescence reflected the AO primary binding sites with chromatin-DNA. Laser flow microfluorimetric measurements showed a bimodal distribution. The higher fluorescence peak corresponded to de-differentiated cells, while the lower one to control differentiated cells. The modified Ringer solution partially triggered the de-differentiation process. When the stimulating electric field was switched on, a frequency window could be found such that if the signal frequency was external (internal) to the window, the process was inhibited (enhanced). Preliminary automated image analysis of cell smears suggest that de-differentiated and normal cells have the same integrated optical density but different nuclear areas. The findings suggest that the first stage of the de-differentiation process, when cells move from an inactive state toward an active one, is the unfolding of their chromatin supercoiling, without any DNA synthesis. It is concluded that cytofluorimetry offers reliable means of evaluating the effects of electromagnetic stimulation.

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